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16. Abstract

The purpose of this Ventilation System Compliance Guideline is to provide manufacturers of recreational boats subject to the Ventilation Standard in 33 CFR 183, Subpart K, with a guide to methods, which if they are followed, will be acceptable to the Coast Guard as meeting the intent and purpose of the regulations.

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This report does not constitute a standard, specification or regulation.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in²	square inches	6.5	square centimeters	cm²
ft²	square feet	0.09	square meters	m²
yd²	square yards	0.8	square meters	m²
mi²	square miles	2.6	square kilometers	km²
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft³	cubic feet	0.03	cubic meters	m³
yd³	cubic yards	0.76	cubic meters	m³
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 cm (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25 SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm²	square centimeters	0.16	square inches	in²
m²	square meters	1.2	square yards	yd²
km²	square kilometers	0.4	square miles	mi²
ha	hectares (10,000 m²)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m³	cubic meters	35	cubic feet	ft³
m³	cubic meters	1.3	cubic yards	yd³
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

°F -40   0   32   80   98.6   120   160   200   212
°C -40   -20   0   20   37   40   60   80   100

FOREWORD

THIS VENTILATION SYSTEM COMPLIANCE GUIDELINE WAS PREPARED BY THE AMERICAN BOAT AND YACHT COUNCIL (ABYC), A NON-PROFIT PUBLIC SERVICE ORGANIZATION, UNDER A U.S. COAST GUARD CONTRACT AWARDED TO ABYC PURSUANT TO THE AUTHORITY CONTAINED IN SECTION 25 OF THE FEDERAL BOAT SAFETY ACT OF 1971 (P. L. 92-75).

THIS GUIDELINE DOES NOT DICTATE THE METHODS A MANUFACTURER MUST FOLLOW TO COMPLY WITH THE REGULATIONS, BUT IT IS INTENDED TO BE USED AS A GUIDE TO METHODS WHICH, IF THEY ARE FOLLOWED, WILL BE ACCEPTABLE TO THE COAST GUARD AS MEETING THE INTENT AND PURPOSE OF THE REGULATIONS.

THE MEMBERS OF ABYC HAVE MADE EVERY EFFORT TO MAKE THIS GUIDELINE ACCURATE AND CONSISTENT WITH THE VENTILATION SYSTEM REGULATIONS, AND THE COAST GUARD HAS REVIEWED IT FOR ANY INCONSISTENCIES. IN CASES WHERE IT APPEARS A CONFLICT MAY EXIST, HOWEVER, USERS OF THIS GUIDELINE SHOULD ADHERE TO THE REQUIREMENTS OF THE REGULATIONS AND NOT THE SUGGESTED METHODS FOR COMPLIANCE DESCRIBED IN THIS GUIDELINE. ANY QUESTIONS SHOULD BE DIRECTED TO YOUR COAST GUARD DISTRICT BOATING STANDARDS OFFICE.

THE COAST GUARD WISHES TO THANK THE MEMBERS OF ABYC WHO CONTRIBUTED THEIR PERSONAL TIME TO THE DEVELOPMENT OF THIS COMPLIANCE GUIDELINE. THE GUIDELINE WILL AID SMALL VOLUME BOATBUILDERS WHO LACK LARGE ENGINEERING STAFFS AND EXTENSIVE ENGINEERING CAPABILITIES IN COMPLYING WITH THE REGULATIONS. THE RECREATIONAL BOATING PUBLIC WILL SOON REALIZE THE BENEFITS OF THE VENTILATION SYSTEM REGULATIONS THROUGH A REDUCTION IN THE INCIDENCE OF FIRES AND EXPLOSIONS ABOARD RECREATIONAL BOATS.

H. W. PARKER
Rear Admiral, U. S. Coast Guard
Chief, Office of Boating, Public,
and Consumer Affairs

Dist: (SDL No. 114)
A: None
B: c(6); n(50)
C: None
D: None
E: None
F: None

VENTILATION SYSTEM COMPLIANCE GUIDELINE

INTRODUCTION

The ventilation regulation is the third of a series of interrelated regulations designed to reduce accidents involving fires and explosions on boats. The other two regulations are 33 CFR Subpart I - Electrical Systems and 33 CFR Subpart J - Fuel Systems. Ventilation's role is to remove potentially flammable and explosive vapors that may occur during the normal operation of a boat. Ventilation can not be relied upon to maintain a safe atmosphere in the presence of leaking fuel or liquid fuel.

In consideration of the stated limitations the regulation has selected critical areas pertaining to ventilation systems from the standpoint of safety and stipulates requirements to assure good practice is adhered to in these areas. There may be more than one solution to the problem of providing sufficient ventilation for a particular boat. The regulation offers alternatives and states most of the requirements in terms of performance. The provision of these alternatives and the possible interpretations of the requirements may be confusing to those using these regulations.

Regulations are typically written in concise terms, the words and arrangement chosen to be enforceable and in some cases to be interpreted legally. This format prohibits explanations, recommendations, and easily detected alternate solutions, to be included. A regulation provides an outline about which a great deal of further information, interpretation, explanation, clarification and some helpful hints are needed in order to provide a good understanding of and to aid in compliance with, its intent.

The Ventilation System Compliance Guideline attempts to fulfill the needs of the average boatbuilder in order to assist in achieving compliance with the ventilation regulations. It explains, interprets, clarifies, discusses alternates, diagrams, tabulates, makes some recommendations and in general complements the regulation to improve the boat builder's understanding.

CAUTION

This guideline only addresses provisions of the Federal Regulations. It is not a complete engineering manual for the design of ventilation systems for boats. There are other manuals and standards available for this purpose.

THE GUIDELINE FORMAT

The format of this guideline has been chosen to follow the sequence of requirements in the ventilation regulation. Obviously other arrangements could have been chosen, however this format provides the many boatbuilders and component suppliers who have followed the development of the regulations a familiar sequence of information, thereby reducing confusion.

Each portion of the regulation has been stated in the box identified by **IT'S THE LAW**. The effective date of the requirement is stated and a discussion follows. The discussion explains, interprets, clarifies, identifies interdependence of requirements and is designed to improve the understanding of the intent of the regulatory requirement. Diagrams are freely used and tables included wherever they can be helpful.

The discussion, diagrams, and tables are followed by a box identified by **DO YOU COMPLY**, which asks questions to which the answer must be YES if compliance is to be achieved. This provides a checklist for each regulatory requirement.

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183.601   APPLICABILITY

This subpart applies to all boats that –

(a)   Have gasoline engines for electrical generation, mechanical power, or propulsion; and

(b)   Are built after July 31, 1980, except that a manufacturer may elect to comply with this subpart at any time after July 31, 1978.

FIGURE 1 – APPLICABILITY

THIS SUBPART APPLIES TO ALL BOATS THAT HAVE GASOLINE ENGINES FOR –
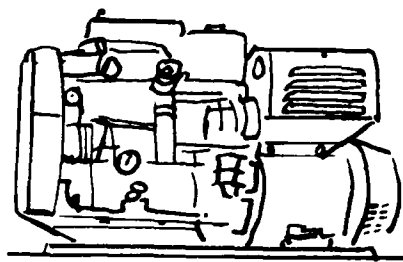
ELECTRICAL GENERATION
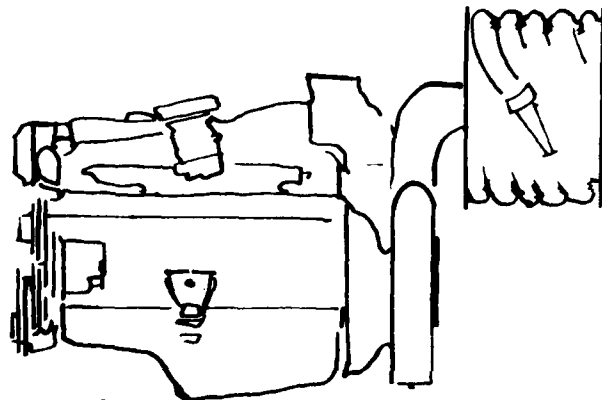
MECHANICAL POWER

–OR PROPULSION
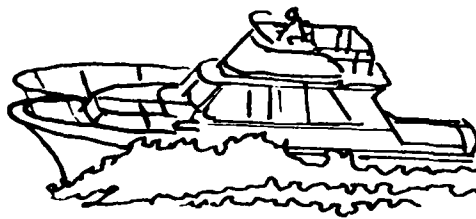
INBOARD
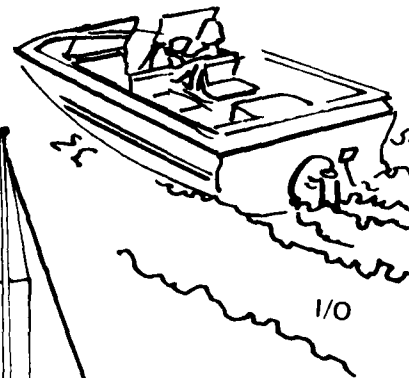
I/O
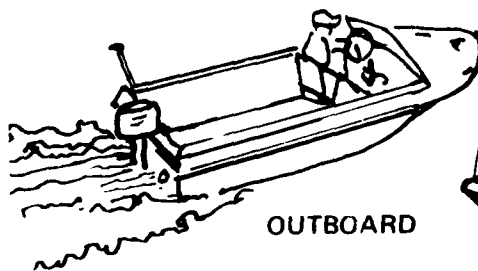
OUTBOARD

AUXILIARY

7
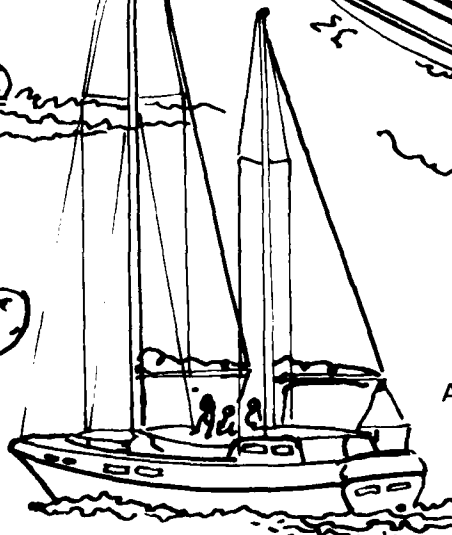
DO YOU COMPLY

To determine if this regulation is applicable:

--   Was the boat built after July 31, 1980?   (   )

--   Is there a gasoline engine on the boat?   (   )

DEFINITIONS

AMCA

ASTM

Fuel

Open to the Atmosphere

UL

IT'S THE LAW

183.605   **DEFINITIONS**

As used in this subpart –

"AMCA" means Air Moving and Conditioning Association.

183.607   **INCORPORATED BY REFERENCE**

(a)(1)   AMCA Standard 210–74, Figure 12, dated 1974.

> Air Moving and Conditioning Association
> 30 West University Avenue
> Arlington Heights
> Illinois 60004

Note 1.   *The present name for AMCA is now Air Movement and Control Association, Inc.*

Note 2.   *See 183.610(b) for reference to AMCA.*

Note 3.   *(183.607(b)*   *The Director of the Federal Register approved the incorporation by reference on March 24, 1978.*

Note 4.   *(183.607(a)*   *This standard is incorporated in the regulation by reference. Copies may be obtained from the AMCA. It is also available for inspection at* –

> *U.S. Coast Guard Headquarters, Room 4220*
> *2100 Second Street, S.W.*
> *Washington, D.C. 20593 and*

> *Office of the Federal Register Library, Room 8401*
> *1100 L Street, N.W.*
> *Washington, D.C. 20408*

AMCA STANDARD 210-74   ASHRAE STANDARD 51-75

LABORATORY METHODS OF TESTING

FANS

FOR RATING PURPOSES

Published by

Air Moving and Conditioning Association, Inc.

and

American Society of Heating, Refrigerating
and Air-Conditioning Engineers

Contents

AMCA STANDARD 210-74   ASHRAE STANDARD 51-75

LABORATORY METHODS OF TESTING FANS FOR RATING PURPOSES

1. Purpose

The purpose of this Standard is to establish uniform methods for laboratory testing of fans and other air moving devices to determine performance in terms of flow rate, pressure, power, air density, speed of rotation, and efficiency, for rating or guarantee purposes.

It is not the purpose of this Standard to specify the testing procedures to be used for design, production, or field testing.

2. Scope

This Standard may be used as the basis for testing fans, blowers, exhausters, compressors, or other air moving devices when air is used as the test gas.

Circulating fans such as ceiling fans and desk fans are not within the scope of this Standard. Compressors with interstage cooling are not within the scope of this Standard. Positive displacement machines are not within the scope of this Standard.

The parties to a test for guarantee purposes may agree on exceptions to this Standard in writing prior to the test. However, only tests which do not violate any mandatory requirements of this Standard shall be designated as tests conducted in accordance with this Standard.

3. Units of Measurement

3.1 System of Units. U.S. customary units are employed in this Standard. Values shall be based on the National Bureau of Standards values which, in turn, are based on the fundamental values of the International Bureau of Weights and Measures [3]. The International System of Units (Le Système International d'Unités) [3] has not been employed in the text, but Appendix A provides conversion factors and coefficients for SI and other metric units.

3.2 Basic Units. The unit of length is either the foot, designated ft, or the inch, designated in. The unit of mass is the pound mass, designated lbm. The unit of time is either the minute, designated min, or the second, designated s. The unit of temperature is either the degree Fahrenheit, designated F, or the degree Rankine, designated R. The unit of force is the pound, designated lb.

3.3 Flow Rate and Velocity. The unit of flow rate is the cubic foot per minute, designated cfm. The unit of velocity is the foot per minute, designated fpm.

3.4 Pressure and Head. The unit of pressure is either the inch water gauge, designated in. wg, or the inch mercury column, designated in. Hg. The unit of head is the foot-pound per pound mass, properly designated ft-lb lbm, but commonly designated ft of air. The in. wg shall be based on a one inch column of distilled water at 68 F under standard gravity and a gas column balancing effect based on standard air. The in. Hg shall be based on a one inch column of mercury at 32 F under standard gravity in vacuo.

3.5 Power, Energy, and Torque. The unit of power is the horsepower, designated hp, or the watt, designated W. In this Standard, the latter is used only for electrical power measurements. The unit of energy is the foot-pound, designated ft-lb. The unit of torque is the pound-inch, designated lb-in.

3.6 Efficiency. Efficiencies are expressed on a per unit basis. Percentage values can be obtained by multiplying by 100.

3.7 Speed. The unit of rotational speed is the revolution per minute, designated rpm.

3.8 Gas Properties. The unit of density is the pound mass per cubic foot, designated lbm ft⁻³. The unit of viscosity is the pound mass per foot-second, designated lbm ft-s. The unit of gas constant is the foot-pound per pound mass-degree Rankine, designated ft-lb lbm- R.

3.9 Dimensionless Groups. Various dimensionless quantities appear in the text. Any consistent system of units may be employed to evaluate these quantities unless a numerical factor is included, in which case units must be as specified.

3.10 Physical Constants. The value of standard gravitational acceleration shall be taken as 32.1740 ft s⁻² at mean sea level at 45 latitude [4]. The density of distilled water at saturation pressure shall be taken as 62.3205 lbm ft⁻³ at 68 F [5]. The density of mercury at saturation pressure shall be taken at 848.714 lbm ft⁻³ at 32 F [5]. The specific weights (lb ft⁻³) of these fluids in vacuo under standard gravity are numerically equal to their densities at corresponding temperatures.

4. Symbols and Subscripts

4.1 Symbols and Subscripted Symbols

SYMBOL	DESCRIPTION	UNIT
A	Area of Cross Section	ft²
C	Nozzle Discharge Coefficient	dimensionless
D	Diameter and Equivalent Diameter	ft
D_h	Hydraulic Diameter	ft
e	Base of Natural Logarithm (2.178 . . .)	dimensionless
E	Energy Factor	dimensionless
F	Beam Load	lb
f	Coefficient of Friction	dimensionless
H	Fan Power Input	hp
H_o	Fan Power Output	hp
K_p	Compressibility Coefficient	dimensionless
L	Nozzle Throat Dimension	ft
L_e	Equivalent Length of Straightener	ft
$L_{x,x'}$	Length of Duct Between Planes x and x'	ft
l	Length of Moment Arm	in.
ln	Natural Logarithm	——
M	Chamber Dimension	ft
N	Speed of Rotation	rpm
n	Number of Readings	dimensionless
P_s	Fan Static Pressure	in. wg
P_{sx}	Static Pressure at Plane x	in. wg
P_t	Fan Total Pressure	in. wg
P_{tx}	Total Pressure at Plane x	in. wg
P_v	Fan Velocity Pressure	in. wg
P_{vx}	Velocity Pressure at Plane x	in. wg
p_b	Corrected Barometric Pressure	in. Hg
p_e	Saturated Vapor Pressure at t_w	in. Hg
p_p	Partial Vapor Pressure	in. Hg
Q	Fan Flow Rate	cfm
Q_x	Flow Rate at Plane x	cfm
R	Gas Constant	ft-lb/lbm-°R
Re	Reynolds Number	dimensionless
T	Torque	lb-in.
t_d	Dry-Bulb Temperature	°F
t_t	Total Temperature	°F
t_w	Wet-Bulb Temperature	°F
V	Velocity	fpm
W	Power Input to Motor	W
x	Function Used to Determine K_p	dimensionless
Y	Nozzle Expansion Factor	dimensionless
y	Thickness of Straightener Element	ft
z	Function Used to Determine K_p	dimensionless
α	Static Pressure Ratio for Nozzles	dimensionless
β	Diameter Ratio for Nozzles	dimensionless
γ	Ratio of Specific Heats	dimensionless
ΔP	Pressure Differential	in. wg
η	Motor Efficiency	per unit
η_s	Fan Static Efficiency	per unit
η_t	Fan Total Efficiency	per unit
μ	Air Viscosity	lbm/ft-s
ρ	Fan Air Density	lbm/ft³
ρ_x	Air Density at Plane x	lbm/ft³
Σ	Summation Sign	——

4.2 Additional Subscripts

SUBSCRIPT	DESCRIPTION
c	Converted value
r	Reading
x	Plane 0,1,2...... as appropriate
0	Plane 0 (general test area)
1	Plane 1 (fan inlet)
2	Plane 2 (fan outlet)
3	Plane 3 (Pitot traverse station)
4	Plane 4 (duct piezometer station)
5	Plane 5 (nozzle inlet station in chamber)
6	Plane 6 (nozzle discharge station)
7	Plane 7 (outlet chamber measurement station)
8	Plane 8 (inlet chamber measurement station)

5. Definitions

5.1 Fans

5.1.1 Fan. A fan is a device for moving air which utilizes a power driven rotating impeller. A fan shall have at least one inlet opening and at least one outlet opening. The openings may or may not have elements for connection to duct-work. A fan may have various appurtenances which affect performance. It is necessary to establish which appurtenances are to be considered a part of the fan for testing purposes.

5.1.2 Fan Outlet Area. Fan outlet area is the gross inside area measured in the planes of the outlet openings. For roof ventilators, the area shall be considered the gross impeller outlet area for centrifugal types or the gross casing area at the impeller for axial types.

5.1.3 Fan Inlet Area. Fan inlet area is the gross inside area measured in the planes of the inlet connections. For converging inlets without connection elements, the inlet area shall be considered to be that where a plane, perpendicular to the air stream, first meets the bell mouth or cone.

5.2 Psychrometrics

5.2.1 Dry-Bulb Temperature. Dry-bulb temperature is the air temperature measured by a dry temperature sensor.

5.2.2 Wet-Bulb Temperature. Wet-bulb temperature is the temperature measured by a temperature sensor covered by a water-moistened wick and exposed to air in motion. When properly measured, it is a close approximation of the temperature of adiabatic saturation.

5.2.3 Wet-Bulb Depression. Wet-bulb depression is the difference between the dry-bulb and wet-bulb temperatures at the same location.

5.2.4 Total Temperature. Total temperature is the temperature which exists by virtue of the internal and kinetic energy of the air. If the air is at rest, the total temperature will equal the static temperature.

5.2.5 Static Temperature. Static temperature is the temperature which exists by virtue of the internal energy of the air only. If a portion of the internal energy is converted into kinetic energy, the static temperature will be decreased accordingly.

5.2.6 Air Density. Air density is the mass per unit volume of the air.

5.2.7 Standard Air. Standard air is air with a density of 0.075 lbm/ft, a ratio of specific heats of 1.400, a viscosity of 1.222×10^{-5} lbm/ft-s, and an absolute pressure of 408.0 in. wg. Air at 68 F, 50% relative humidity, and 29.92 in. Hg has these properties, approximately.

5.3 Pressure and Head

5.3.1 Pressure. Pressure is force per unit area. This corresponds to energy per unit volume of fluid.

5.3.2 Absolute Pressure. Absolute pressure is the value of a pressure when the datum pressure is absolute zero. It is always positive.

5.3.3 Barometric Pressure. Barometric pressure is the absolute pressure exerted by the atmosphere.

5.3.4 Gauge Pressure. Gauge pressure is the value of a pressure when the datum pressure is the barometric pressure at the point of measurement. It may be negative or positive.

5.3.5 Velocity Pressure. Velocity pressure is that portion of the air pressure which exists by virtue of the rate of motion only. It is always positive.

5.3.6 Static Pressure. Static pressure is that portion of the air pressure which exists by virtue of the degree of compression only. It may be negative or positive.

5.3.7 Total Pressure. Total pressure is the air pressure which exists by virtue of the degree of compression and the rate of motion. It is the algebraic sum of the velocity pressure and the static pressure at a point. Thus, if the air is at rest, the total pressure will equal the static pressure.

5.3.8 Pressure Loss. Pressure loss is the change in total pressure due to friction and turbulence.

5.3.9 Head. Head is the useful energy per unit mass of fluid added by the fan. Heads corresponding to total, velocity, or static pressure may be used, but they are not employed in this Standard.

5.4 Fan Performance Variables

5.4.1 Fan Air Density. Fan air density is the density of the air corresponding to the total pressure and total temperature at the fan inlet [6].

5.4.2 Fan Flow Rate. Fan flow rate is the volumetric flow rate at fan air density.

5.4.3 Fan Total Pressure. Fan total pressure is the difference between the total pressure at the fan outlet and the total pressure at the fan inlet.

5.4.4 Fan Velocity Pressure. Fan velocity pressure is the pressure corresponding to the average velocity at the fan outlet.

5.4.5 Fan Static Pressure. Fan static pressure is the difference between the fan total pressure and the fan velocity pressure. Therefore, fan static pressure is the difference between the static pressure at the fan outlet and the total pressure at the fan inlet.

5.4.6 Fan Speed. Fan speed is the rotative speed of the impeller. If a fan has more than one impeller, fan speeds are the rotative speeds of each impeller.

5.4.7 Compressibility Coefficient. Compressibility coefficient is a thermodynamic factor which must be applied to determine fan total efficiency from fan flow rate, fan total pressure, and fan power input. This coefficient is derived in Appendix B. It may be considered to be the ratio of the mean flow rate through the fan to the flow rate at fan air density. It is also the ratio of the fan total pressure that would be developed with an incompressible fluid to the fan total pressure that is developed with a compressible fluid.

5.4.8 Fan Power Output. Fan power output is the useful power delivered to the air. This is proportional to the product of fan flow rate and fan total pressure and compressibility coefficient.

5.4.9 Fan Power Input. Fan power input is the power required to drive the fan and any elements in the drive train which are considered a part of the fan.

5.4.10 Fan Total Efficiency. Fan total efficiency is the ratio of the fan power output to the fan power input.

5.4.11 Fan Static Efficiency. Fan static efficiency is the fan total efficiency multiplied by the ratio of fan static pressure to fan total pressure.

5.4.12 Fan Total Head. Fan total head is proportional to fan total pressure times compressibility coefficient divided by fan air density.

5.4.13 Fan Velocity Head. Fan velocity head is proportional to fan velocity pressure divided by fan air density.

5.4.14 Fan Static Head. Fan static head is the difference between fan total head and fan velocity head.

5.5 Miscellaneous

5.5.1 Point of Operation. Point of operation is the relative position on the fan characteristic curve corresponding to a particular flow rate. It is controlled during a test by adjusting the position of the throttling device, by changing flow nozzles or auxiliary fan characteristics, or by any combination of these.

5.5.2 Free Delivery. Free delivery is the point of operation where the fan static pressure is zero.

5.5.3 Shut Off. Shut off is the point of operation where the fan flow rate is zero.

5.5.4 Determination. A determination is a complete set of measurements for a particular point of operation of a fan. The measurements must be sufficient to determine all fan performance variables as defined in 5.4.

5.5.5 Test. A test is a series of determinations for various points of operation of a fan.

5.5.6 Energy Factor. Energy factor is the ratio of the total kinetic energy of the flow to the kinetic energy corresponding to the average velocity.

6. Instruments and Methods of Measurement

6.1 Accuracy [7]. The specifications for instruments and methods of measurement which follow include accuracy requirements. The specified requirements correspond to two standard deviations and are based on an assumed normal distribution of the errors involved. The calibration procedures which are specified shall be employed to minimize systematic errors. Random errors can be established only from an adequate statistical sample. It is anticipated that calibration data will be accumulated on the various instruments prior to their selection for use in a particular test. Instrument errors shall be such that two standard deviations of the accumulated data from their mean do not exceed the specified values.

6.2 Pressure. The total pressure at a point shall be measured on an indicator, such as a manometer, with one leg open to atmosphere and the other leg connected to a total pressure sensor, such as a total pressure tube or the impact tap of a Pitot-static tube. The static pressure at a point shall be measured on an indicator, such as a manometer, with one leg open to atmosphere and the other leg connected to a static pressure sensor, such as a static pressure tap or the static tap of a Pitot-static tube. The velocity pressure at a point shall be measured on an indicator, such as a manometer, with one leg connected to a total pressure sensor, such as the impact tap of a Pitot-static tube, and the other leg connected to a static pressure sensor, such as the static tap of the same Pitot-static tube. The differential pressure between two points shall be measured on an indicator, such as a manometer, with one leg connected to the upstream sensor, such as a static pressure tap, and the other leg connected to the downstream sensor, such as a static pressure tap.

6.2.1 Manometers and Other Pressure Indicating Instruments. Pressure shall be measured on manometers of the liquid column type using inclined or vertical legs or other instruments which provide a maximum error of 1% of the maximum observed reading or 0.005 in. wg whichever is larger.

6.2.1.1 Calibration. Each pressure indicating instrument shall be calibrated at both ends of the scale and at least nine equally spaced intermediate points in accordance with the following:

(1) When the pressure to be indicated falls in the range of 0 to 10 in. wg. calibration shall be against a water-filled hook gauge of the micrometer type or a precision micromanometer.

(2) When the pressure to be indicated is *above 10 in. wg. calibration shall be against a water-filled hook gauge of the micrometer type, a precision micromanometer, or a water-filled U-tube.*

6.2.1.2 Averaging. Since the flow and the pressures produced by a fan are never strictly steady, the pressure indicated on any instrument will fluctuate with time. In order to obtain a true reading, either the instrument must be damped or the readings must be averaged in a suitable manner. Averaging can sometimes be accomplished mentally, particularly if the fluctuations are small and regular. Multi-point or continuous record averaging can be accomplished with instruments and analyzers designed for this purpose.

6.2.1.3 Corrections. Manometer readings should be corrected for any difference in specific weight of gauge fluid from standard, any difference in gas column balancing effect from standard, or any change in length of the graduated scale due to temperature. However, corrections may be omitted for temperatures between 58 and 78, latitudes between 30 and 60, and elevations up to 5000 ft.

6.2.2 Pitot-Static Tubes [8] [9]. The total pressure or the static pressure at a point may be sensed with a Pitot-static tube of the proportions shown in Figure 1. Either or both of these pressure signals can then be transmitted to a manometer or other indicator. If both pressure signals are transmitted to the same indicator, the differential shall be considered the velocity pressure at the point of the impact opening.

6.2.2.1 Calibration. Pitot-static tubes having the proportions shown in Figure 1 are considered primary instruments and need not be calibrated provided they are maintained in the specified condition.

6.2.2.2 Size. The Pitot-static tube shall be of sufficient size and strength to withstand the pressure forces exerted upon it. The outside diameter of the tube shall not exceed 1 30 of the test duct diameter except that when the length of the supporting stem exceeds 24 tube diameters, the stem may be progressively increased beyond this distance. The minimum practical tube diameter is 0.10 in.

6.2.2.3 Support. Rigid support shall be provided to hold the Pitot-static tube axis parallel to the axis of the duct within 1 degree and at the head locations specified in Figure 3 within 0.05 in. or 0.25% of the duct diameter, whichever is larger. Straighteners are specified so that flow lines will be approximately parallel to the duct axis.

6.2.3 Static Pressure Taps [10]. The static pressure at a point may be sensed with a pressure tap of the proportions shown in Figure 2. The pressure signal can then be transmitted to an indicator.

6.2.3.1 Calibration. Pressure taps having the proportions shown in Figure 2 are considered primary instruments and need not be calibrated provided they are maintained in the specified condition. Every precaution should be taken to insure that the air velocity does not influence the pressure measurement.

6.2.3.2 Averaging. An individual pressure tap is sensitive only to the pressure in the immediate vicinity of the hole. In order to obtain an average, at least four identical taps shall be manifolded into a piezometer ring. The manifold shall have an inside area at least four times that of each tap.

6.2.3.3 Piezometer Rings. Piezometer rings are specified for upstream and downstream nozzle taps and for outlet duct or chamber measurements unless Pitot traverse is specified. Measuring planes shall be located as shown in the figure for the appropriate setup.

6.2.4 Total Pressure Tubes. The total pressure in an inlet chamber may be sensed with a stationary tube of the proportions shown in Figure 2. The pressure signal can then be transmitted to an indicator. The tube shall face directly into the air flow and the open end shall be smooth and free from burrs.

6.2.4.1 Calibration. Total pressure tubes of the above description are considered primary instruments and need not be calibrated if they are maintained in the specified condition.

6.2.4.2 Averaging. The total pressure tube is sensitive only to the pressure in the immediate vicinity of the open end. However, since the velocity in an inlet chamber can be considered uniform due to the settling means which are employed, a single measurement will be representative of the average chamber pressure.

6.2.4.3 Location. Total pressure tubes are specified for inlet chambers. Location shall be as shown in the figure for the appropriate setup.

6.2.5 Other Pressure Measuring Systems. Pressure measuring systems consisting of indicators and sensors other than manometers and Pitot-static tubes, static pressure taps, or total pressure tubes may be used if the combined error of the system including any transducers does not exceed the combined error for an appropriate combination of manometers and Pitot-static tubes, static pressure taps, or total pressure tubes. For systems used to determine fan pressure the contribution to combined error in the pressure measurement shall not exceed that corresponding to 1% of the maximum observed static or total pressure reading during a test (indicator tolerance), plus 1% of the actual reading (averaging tolerance). For systems used to determine fan flow rate, the combined error shall not exceed that corresponding to 1% of the maximum observed velocity pressure or pressure differential reading during a test (indicator tolerance) plus 1% of the actual reading (averaging tolerance).

6.3 Flow Rate. Flow rate shall be calculated either from measurements of velocity pressure obtained by Pitot traverse or from measurements of pressure differential across a flow nozzle.

6.3.1 Pitot Traverse. Flow rate may be calculated from the velocity pressures obtained by traverses of a duct with a Pitot-static tube for any point of operation from free delivery to shut off provided the average velocity corresponding to the flow rate at free delivery at the test speed is at least 2400 fpm [11].

6.3.1.1 Stations. The number and locations of the measuring stations on each diameter and the number of diameters shall be as specified in Figure 3.

6.3.1.2 Averaging. The stations shown in Figure 3 are located on each diameter according to the log-linear rule [12]. The arithmetic mean of the individual velocity measurements made at these stations will be the mean velocity through the measuring section for a wide variety of profiles [13].

6.3.2 Nozzles. Flow rate may be calculated from the pressure differential measured across a flow nozzle or bank of nozzles for any point of operation from free delivery to shut off provided the average velocity at the nozzle discharge corresponding to the flow rate at free delivery at the test speed is at least 2800 fpm [11].

6.3.2.1 Size. The nozzle or nozzles shall conform to Figure 4. Nozzles may be of any convenient size. However, when a duct is connected to the inlet of the nozzle, the ratio of nozzle throat diameter to the diameter of the inlet duct shall not exceed 0.525.

6.3.2.2 Calibration. The standard nozzle is considered a primary instrument and need not be calibrated if maintained in the specified condition. Reliable coefficients have been established for throat dimensions L = 0.5 D and L = 0.6 D, shown in Figure 4 [14]. Throat dimension L = 0.6 D is recommended for new construction.

6.3.2.3 Chamber Nozzles. Nozzles without integral throat taps may be used for multiple nozzle chambers in which case upstream and downstream pressure taps shall be located as shown in the figure for the appropriate setup. Alternatively, nozzles with throat taps may

be used in which case the throat taps located as shown in Figure 4 shall be used in place of the downstream pressure taps shown in the figure for the setup and the piezometer for each nozzle shall be connected to its own indicator.

6.3.2.4 Ducted Nozzles. Nozzles with integral throat taps shall be used for ducted nozzle setups. Upstream pressure taps shall be located as shown in the figure for the appropriate setup. Downstream taps are the integral throat taps and shall be located as shown in Figure 4.

6.3.2.5 Taps. All pressure taps shall conform to the specification in 6.2.3 regarding geometry, number, and manifolding into piezometer rings.

6.3.3 Other Flow Measuring Methods. Flow measuring methods which utilize meters or traverses other than flow nozzles or Pitot traverses may be used if the error introduced by the method does not exceed that introduced by an appropriate flow nozzle or Pitot traverse method. The contribution to the combined error in the flow rate measurement shall not exceed that corresponding to 1.2% of the discharge coefficient for a flow nozzle [15].

6.4 Power. Power shall be determined from the beam load measured on a reaction dynamometer, the torque measured on a torsion element, or the electrical input measured on a calibrated motor.

6.4.1 Reaction Dynamometers. A cradle or torque table type reaction dynamometer having a demonstrated accuracy of ± 2% of observed reading may be used to measure power.

6.4.1.1 Calibration. A reaction dynamometer shall be calibrated through its range of usage by suspending weights from a torque arm. The weights shall have certified accuracies of ± 0.2%. The length of the torque arm shall be determined to an accuracy of ± 0.2%.

6.4.1.2 Tare. The zero torque equilibrium (tare) shall be checked before and after each test. The difference shall be within 0.5% of the maximum value measured during the test.

6.4.2 Torsion Devices. A torque meter having a demonstrated accuracy of ± 2% of observed reading may be used to determine power.

6.4.2.1 Calibration. A torsion device shall have a static calibration and may have a running calibration through its range of usage. The static calibration shall be made by suspending weights from a torque arm. The weights shall have certified accuracies of ± 0.2%. The length of the torque arm shall be determined to an accuracy of ± 0.2%.

6.4.2.2 Tare. The zero torque equilibrium (tare) and the span of the readout system shall be checked before and after each test. In each case, the difference shall be within 0.5% of the maximum value measured during the test.

6.4.3 Calibrated Motors. A calibrated electric motor may be used with suitable electrical meters to measure power.

6.4.3.1 Calibration. The motor shall be calibrated through its range of usage against an absorption dynamometer except as provided in 6.4.3.4 The absorption dynamometer shall be calibrated by suspending weights from a torque arm. The weights shall have certified accuracies of ± 0.2%. The length of the torque arm shall be determined to an accuracy of ± 0.2%.

6.4.3.2 Meters. Electrical meters shall have certified accuracies of ± 1.0% of observed reading. It is preferable that the same meters be used for the test as for the calibration.

6.4.3.3 Voltage. The motor input voltage during the test shall be within 1% of the voltage observed during calibration. If air flows over the motor from the fan under test, similar flow shall be provided during calibration.

6.4.3.4 IEEE. Polyphase induction motors may be calibrated using the IEEE Segregated-Loss Method [16].

6.4.4 Averaging. Since the power required by a fan is never strictly steady, the torque measured on any instrument will fluctuate with time. In order to obtain a true reading, either the instrument must be damped or the readings must be averaged in a suitable manner. Averaging can sometimes be accomplished mentally, particularly if the fluctuations are small and regular. Multi-point or continuous record averaging can be accomplished with instruments and analyzers designed for this purpose.

6.5 Speed. Speed shall be measured with a revolution counter and chronometer, a stroboscope and chronometer, a precision instantaneous tachometer, an electronic counter-timer, or any other device which has a demonstrated accuracy of ± 0.5% of the value being measured.

6.5.1 Strobes. A stroboscopic device triggered by the line frequency of a public utility is considered a primary instrument and need not be calibrated if it is maintained in good condition.

6.5.2 Chronometers. A quality watch with a sweep second hand that keeps time within two minutes per day is considered a primary instrument.

6.5.3 Other Devices. The combination of a line frequency strobe and chronometer shall be used to calibrate all other speed measuring devices. Friction driven counters shall not be used when they can influence the speed due to drag.

6.6 Air Density. Air density shall be calculated from measurements of wet-bulb temperature, dry-bulb temperature, and barometric pressure. Other parameters may be measured and used if the maximum error in the calculated density does not exceed 0.5%.

6.6.1 Thermometers. Both wet- and dry-bulb temperatures shall be measured with thermometers or other instruments with demonstrated accuracies of ± 2 F and readabilities of 1°F or finer.

6.6.1.1 Calibration. Thermometers shall be calibrated over the range of temperatures to be encountered during test against a thermometer with a calibration that is traceable to the National Bureau of Standards.

6.6.1.2 Wet-Bulb. The wet-bulb thermometer shall have an air velocity over the water-moistened wick-covered bulb of 700 to 2000 fpm [17]. The dry-bulb thermometer shall be mounted upstream of the wet-bulb thermometer so its reading will not be depressed.

6.6.2 Barometers. The barometric pressure shall be measured with a mercury column barometer or other instrument with a demonstrated accuracy of ± 0.05 in. Hg and readable to 0.01 in. Hg or finer.

6.6.2.1 Calibration. Barometers shall be calibrated against a mercury column barometer with a calibration that is traceable to the National Bureau of Standards. A convenient method of doing this is to use an aneroid barometer as a transfer instrument and carry it back and forth to the Weather Bureau Station for comparison [18]. A permanently mounted mercury column barometer should hold its calibration well enough so that comparisons every three months should be sufficient. Transducer type barometers shall be calibrated for each test. Barometers shall be maintained in good condition.

6.6.2.2 Corrections. Barometric readings shall be corrected for any difference in mercury density from standard or any change in length of the graduated scale due to temperature. Refer to manufacturer's instructions.

7. Equipment and Setups

7.1 Ducts. A duct may be incorporated in a laboratory setup to provide a measuring station or to simulate the conditions the fan is expected to encounter in service or both. The dimension D in the test setup figures is the inside diameter of a circular cross-section duct or the equivalent diameter of a rectangular cross-section duct with inside transverse dimensions a and b where $D = \sqrt{4ab/\pi}$.

7.1.1 Flow Measuring Ducts. Ducts with measuring stations for flow determination shall be straight and have uniform circular cross sections. Pitot traverse ducts shall be at least 10 diameters long with the traverse plane located between 8.5 and 8.75 diameters from the upstream end. Such ducts may serve as an inlet or an outlet duct as well as to provide a measuring station. Ducts connected to the upstream side of a flow nozzle shall be between 6.5 and 6.75 diameters long when used only to provide a measuring station or between 9.5 and 9.75 diameters long when used as an outlet duct as well.

7.1.2 Pressure Measuring Ducts. Ducts with stations for pressure measurements shall be straight and may have either uniform circular or rectangular cross sections. Outlet ducts with piezometer rings shall be at least 10 diameters long with the piezometer plane located between 8.5 and 8.75 diameters from the upstream end.

7.1.3 Short Ducts. Outlet ducts in which no measurements are taken shall be between 2 and 3 equivalent diameters long and an area within 0.5% of the fan outlet area and a uniform shape to fit the fan outlet [19].

7.1.4 Transformation Pieces. Transformation pieces shall be used when a duct with a measuring station is to be connected to the fan and it is of a size or shape that differs from the fan connection. Such pieces shall not contain any converging element that makes an angle with the duct axis of greater than 7.5 degrees or a diverging element that makes an angle with the duct axis of greater than 3.5 degrees. The axes of the fan opening and duct shall coincide. See Figure 5. Connecting ducts and elbows of any size and shape may be used between a duct which provides a measuring station and a chamber.

7.1.5 Duct Area. Outlet ducts used to provide measuring stations shall be not more than 5.0% larger or smaller than the fan outlet area. Inlet ducts used to provide measuring stations shall be not more than 12.5% larger nor 7.5% smaller than the fan inlet area.

7.1.6 Roundness. The portion of a Pitot traverse duct within one-half duct diameter of either side of the plane of measurement shall be round within 0.5% of the duct diameter. The remainder of the duct shall be round within 1% of the duct diameter. The area of the plane of measurement shall be determined from the average of four diameters measured at 45° increments. The diameter measurements shall be accurate to 0.2%.

7.1.7 Straighteners. Straighteners shall be used in all ducts which provide measuring stations. The downstream plane of the straightener shall be located between 5 and 5.25 duct diameters upstream of the plane of the Pitot traverse or piezometer station. The form of the straightener shall be as specified in Figure 6 [20]. The dimension D is the inside diameter of a circular cross-section duct or the equivalent diameter of a rectangular cross-section duct with inside transverse dimensions a and b where $D = \sqrt{4ab/\pi}$. The dimension y which is the thickness of the straightener elements, shall not exceed 0.005 D.

7.1.8 Inlet Bells. Inlet bells may be mounted on the fan inlet to simulate an inlet duct. The bell connection shall be the same size and shape as the fan inlet connection. The bell shall have a coefficient of contraction of 0.94 or greater.

7.2 Chambers. A chamber may be incorporated in a laboratory setup to provide a measuring station or to simulate the conditions the fan is expected to encounter in service or both. A chamber may have a circular or rectangular cross-sectional shape. The dimension M in the test setup diagram is the inside diameter of a circular chamber or the equivalent diameter of a rectangular chamber with inside transverse dimensions a and b where

$$M = \sqrt{4ab/\pi}.$$

7.2.1 Outlet Chambers. An outlet chamber shall have a cross-sectional area at least nine times the area of the fan outlet or outlet duct for fans with axis of rotation perpendicular to the discharge flow and a cross-sectional area at least sixteen times the area of the fan outlet or outlet duct for fans with axis of rotation parallel to the discharge flow [21].

7.2.2 Inlet Chambers. Inlet chambers shall have a cross-sectional area at least five times the fan inlet area [21].

7.2.3 Flow Settling Means. Flow settling means shall be installed in chambers where indicated on the test setup figures to provide proper flow patterns [21].

Where a measuring plane is located downstream of the settling means, the settling means is provided to insure a substantially uniform flow ahead of the measuring plane. In this case, the maximum velocity at a distance 0.2M downstream of the screen shall not exceed the average velocity by more than 25% unless the maximum velocity is less than 400 feet per minute.

Where a measuring plane is located upstream of the settling means, the purpose of the settling screen is to absorb the kinetic energy of the upstream jet, and prevent the generation of excessive recirculation within the chamber. In this case, the maximum reverse velocity in space upstream of the screen shall not exceed 10% of the calculated mean jet velocity.

Where measuring planes are located on both sides of the settling means within the chamber, the requirements for each side as outlined above shall be met.

Any combination of screens or perforated plates that will meet these requirements may be used, but in general a reasonable chamber length for the settling means is necessary to meet both requirements. Three uniform square mesh round wire screens spaced 0.1M apart with 60%, 50%, and 45% open areas for the first, second, and third screen respectively. may be considered to meet the above performance specifications. Tolerances of ± 2% open area are allowable.

7.2.4 Multiple Nozzles. Multiple nozzles shall be located as symmetrically as possible. The centerline of each nozzle shall be at least 1.5 nozzle throat diameters from the chamber wall. The minimum distance between centers of any two nozzles in simultaneous use shall be three times the throat diameter of the larger nozzle.

7.3 Variable Supply and Exhaust Systems. A means of varying the point of operation shall be provided in a laboratory setup.

7.3.1 Throttling Devices. Throttling devices may be used to control the point of operation of the fan. Such devices shall be located on the end of the duct or chamber and should be symmetrical about the duct or chamber axis.

7.3.2 Auxiliary Fans. Auxiliary fans may be used to control the point of operation of the test fan. They shall be designed to produce sufficient pressure at the desired flow rate to overcome losses through the test setup. Flow adjustment means, such as dampers, pitch control, or speed control may be required. Auxiliary fans shall not surge or pulsate during tests.

7.4 Setups. Ten setups are diagrammed in Figures 7 through 16.

7.4.1 Leakage. The ducts, chambers, and other equipment utilized shall be designed to withstand the pressure and other forces to be encountered. All joints between the fan and the measuring station shall be sufficiently tight so that measurements are not affected more than one-half the allowable instrument error.

7.4.2 Simulation. The setup shall be capable of duplicating or simulating the inlet and outlet conditions for which the fan is to be rated. The reason for this is that the performance of a fan may be influenced by the inlet and outlet conditions [22]. The simulation of inlet and outlet conditions resulting from anything other than straight ducts or no ducts connected to the fan is beyond the scope of this Standard. However, any appurtenance which is considered a part of the fan shall be in place during testing. If the appurtenance is mounted on the inlet or outlet of the fan, the inlet or outlet of the appurtenance shall be considered the inlet or outlet of the fan.

7.4.3 Selection Guide. The following may be used as a guide to the selection of a proper setup.

(1) Figures 7 through 10 may be used for tests of fans intended to be rated with outlet ducts and with or without inlet ducts.

(2) Figures 11 through 15 may be used for tests of fans intended to be rated with or without outlet ducts and with or without inlet ducts.

(3) Figure 16 may be used for tests of fans intended to be rated with inlet ducts and with or without outlet ducts.

8. Observations and Conduct of Test

8.1 General Test Requirements

8.1.1 Determinations. The number of determinations required to establish the performance of a fan over the range from shut off to free delivery will depend on the shapes of the various characteristic curves. Plans shall be made to vary the opening of the throttling device in such a way that the test points will be well spaced. For smooth characteristics, at least eight determinations shall be made. Additional determinations may be required to define curves which are not smooth. When performance at one point of operation only is required, at least three determinations shall be made to define a short curve which includes that point.

8.1.2 Equilibrium. Equilibrium conditions shall be established before each determination. To test for equilibrium, trial observations shall be made until steady readings are obtained. Ranges of air delivery over which equilibrium cannot be established shall be recorded.

8.1.3 Stability. Any bi-stable performance points (air flow rates at which two different pressure values can be measured) shall be so reported. When they are a result of hysteresis, the points shall be identified as that for decreasing air flow rate and that for increasing air flow rate.

8.2 Data to be Recorded

8.2.1 Test Unit. The description of the test unit shall be recorded. The nameplate data should be copied. Dimensions should be checked against a drawing and a copy of the drawing attached to the data.

8.2.2 Test Setup. The description of the test setup including specific dimensions shall be recorded. Reference may be made to the figures in this Standard. Alternatively, a drawing or annotated photograph of the setup may be attached to the data.

8.2.3 Instruments. The instruments and apparatus used in the test shall be listed. Names, model numbers, serial numbers, scale ranges, and calibration information should be recorded.

8.2.4 Test Data. Test data for each determination shall be recorded. Readings shall be made simultaneously whenever possible.

8.2.4.1 All Tests. For all types of tests, three readings of ambient dry-bulb temperature (t_{do}), ambient wet-bulb temperature (t_{wo}), ambient barometric pressure (p_b), fan outlet dry-bulb temperature (t_{d2}), fan speed (N), and either beam load (F), torque (T), or power input to motor (W) shall be recorded unless the readings are steady in which case only one need be recorded.

8.2.4.2 Pitot Test. For Pitot traverse tests, one reading each of velocity pressure (P_{va}) and static pressure (P_{sa}) shall be recorded for each Pitot station. In addition, three readings of traverse-plane dry-bulb temperature (t_{d}) shall be recorded unless the readings are steady in which case only one need be recorded.

8.2.4.3 Duct Nozzle Tests. For duct nozzle tests, one reading each of pressure drop (ΔP), approach dry-bulb temperature (t_{d5}), and approach static pressure (P_{s5}) shall be recorded.

8.2.4.4 Chamber Nozzle Tests. For chamber nozzle tests, one reading each of pressure drop (ΔP), approach dry-bulb temperature (t_{d5}), and approach static pressure (P_{s5}) shall be recorded.

8.2.4.5 Inlet Chamber Tests. For inlet chamber tests, one reading each of inlet chamber dry-bulb temperature (t_{dx}) and inlet chamber total pressure (P_{tx}) shall be recorded.

8.2.4.6 Outlet Chamber Tests. For outlet chamber tests, one reading each of outlet chamber dry-bulb temperature (t_{d7}) and outlet chamber static pressure (P_{s7}) shall be recorded.

8.2.4.7 Outlet Duct Chamber Tests. For outlet duct chamber tests, one reading each of outlet duct dry-bulb temperature (t_{d4}) and outlet duct static pressure (P_{s4}) shall be recorded.

8.2.4.8 Low Pressure Tests. For tests where P_s is less than 4 in. wg the temperatures may be considered uniform throughout the test setup and only t_{do} and t_{wo} need be measured.

8.2.5 Personnel. The names of test personnel shall be listed with the data for which they are responsible.

9. Calculations

9.1 Calibration Correction. Calibration corrections, when required, shall be applied to individual readings before averaging or other calculations. Calibration corrections need not be made if the correction is smaller than one half the maximum allowable error as specified in Section 6.

9.2 Density and Viscosity of Air

9.2.1 Atmospheric Air Density. The density of atmospheric air (ρ_o) shall be determined from measurements, taken in the general test area, of dry-bulb temperature (t_{do}), wet-bulb temperature (t_{wo}), and barometric pressure (p_b) using either Figure 17, Table 1, or the following formulae [23] [24]:

$$p_s = 2.96 \times 10^{-4} t_{wo}^2 - 1.59 \times 10^{-2} t_{wo} + 0.41,$$

$$p_p = p_s - p_b\left(\frac{t_{do} - t_{wo}}{2700}\right), \text{ and}$$

$$\rho_o = \frac{70.73(p_b - 0.378p_p)}{R(t_{do} + 459.7)}.$$

The first equation is approximately correct for p_s for a range of t_{wo} between 40°F and 90°F. More precise values of p_s can be obtained from the ASHRAE Handbook of Fundamentals [25]. The gas constant (R) may be taken as 53.35 ft-lb/lbm-°R for air.

9.2.2 Duct or Chamber Air Density. The density of air in a duct or chamber at Plane x (ρ_x) may be calculated by correcting the density of atmospheric air (ρ_o) for the pressure (P_{sx}) and temperature (t_{dx}) at Plane x using

$$\rho_x = \rho_o\left(\frac{t_{do} + 459.7}{t_{dx} + 459.7}\right)\left(\frac{P_{sx} + 13.63p_b}{13.63p_b}\right).$$

If P_{sx} is numerically less than 4 in. wg, ρ_x may be considered equal to ρ_o.

9.2.3 Fan Air Density. The fan air density (ρ) shall be calculated from the density of atmospheric air (ρ_o), the total pressure at the fan inlet (P_{t1}), and the total temperature at the fan inlet (t_{t1}) using

$$\rho = \rho_o\left(\frac{P_{t1} + 13.63p_b}{13.63p_b}\right)\left(\frac{t_{do} + 459.7}{t_{t1} + 459.7}\right).$$

On all outlet duct and outlet chamber setups, P_{t1} is equal to zero and t_{t1} is equal to t_{ao}. On all inlet chamber setups, P_{t1} is equal to P_{tx} and t_{t1} is equal to t_{dx}. On the inlet duct setup, t_{t1} is equal to t_{do} and P_{t1} may be considered equal to P_{t3} for fan air density calculations.

9.2.4 Air Viscosity. The viscosity (μ) shall be calculated from

$$\mu = (11.00 + 0.018t_d) \times 10^{-6}.$$

The value for 68°F air which is 1.222×10^{-5} lbm/ft-s may be used for temperatures ranging between 40°F and 100°F [26].

9.3 Fan Flow Rate at Test Conditions

9.3.1 Pitot Traverse. The fan flow rate may be calculated from velocity pressure measurements (P_{v3r}) taken by Pitot traverse.

9.3.1.1 Velocity Pressure. The velocity pressure (P_{v3}) corresponding to the average velocity shall be obtained by taking the square roots of the individual measurements (P_{v3r}), summing the roots, dividing the sum by the number of measurements (n), and squaring the quotient as indicated by

$$P_{v3} = \left(\frac{\Sigma\sqrt{P_{v3r}}}{n}\right)^2.$$

9.3.1.2 Velocity. The average velocity (V_3) shall be obtained from the density at the plane of traverse (ρ_3) and the corresponding velocity pressure (P_{v3}) using

$$V_3 = 1096\sqrt{P_{v3}/\rho_3}.$$

9.3.1.3 Flow Rate. The flow rate (Q_3) at the Pitot traverse plane shall be obtained from the velocity (V_3) and the area (A_3) using $Q_3 = V_3 A_3$.

9.3.1.4 Fan Flow Rate. The fan flow rate at test conditions (Q) shall be obtained from the equation of continuity,

$$Q = Q_3(\rho_3/\rho).$$

9.3.2 Nozzle. The fan flow rate may be calculated from the pressure differential (ΔP) measured across a single nozzle or a bank of multiple nozzles.

9.3.2.1 Alpha Ratio. The ratio (α) of absolute nozzle exit pressure to absolute approach pressure shall be calculated from

$$\alpha = \frac{P_{s6} + 13.63 p_b}{P_{sx} + 13.63 p_b}, \ or$$

$$\alpha = 1 - \frac{5.187 \Delta P}{\rho_x R (t_{dx} + 459.7)}$$

The gas constant (R) may be taken as 53.35 ft-lb lbm- R for air. Plane x is Plane 4 for duct approach or Plane 5 for chamber approach.

9.3.2.2 Beta Ratio. The ratio (β) of nozzle exit diameter (D_6) to approach duct diameter (D_x) shall be calculated from

$$\beta = D_6/D_x.$$

For a duct approach $D_x = D_4$. For a chamber approach, $D_x = D_5$, and β may be taken as zero.

9.3.2.3 Expansion Factor. The expansion factor (Y) may be obtained from Table 2 or

$$Y = \left[\frac{\gamma}{\gamma - 1} \alpha^{2/\gamma} \frac{1 - \alpha^{(\gamma-1)/\gamma}}{1 - \alpha} \right]^{1/2} \left[\frac{1 - \beta^4}{1 - \beta^4 \alpha^{2/\gamma}} \right]^{1/2}.$$

The ratio of specific heats (γ) may be taken as 1.400 for air. Alternatively, the expansion factor for air may be approximated with sufficient accuracy under this Standard using

$$Y = 1 - (0.548 + 0.71\beta^4)(1 - \alpha).$$

9.3.2.4 Energy Factor. The energy factor (E) may be determined by measuring velocity pressures (P_v) upstream of the nozzle at standard traverse stations and calculating

$$E = \left(\frac{\Sigma (P_{v}^{1/2})}{n} \right) \Big/ \left(\frac{\Sigma (P_{v}^{1/2})}{n} \right)^4.$$

Sufficient accuracy can be obtained for setups qualifying under this Standard by setting $E = 1.0$ for chamber approach or $E = 1.043$ for duct approach [14].

9.3.2.5 Reynolds Number. The Reynolds number (Re) based on nozzle exit diameter (D_6) in ft shall be calculated from

$$Re = \frac{D_6 V_6 \rho_6}{60 \mu_6}$$

using properties of air as determined in 9.2 and the appropriate velocity (V_6) in fpm. Since the velocity determination depends on Reynolds number an approximation must be employed. It can be shown that

$$Re = \frac{1096}{60 \mu_6} CD_6 Y \sqrt{\frac{\Delta P \rho_x}{1 - E\beta^4}}$$

For duct approach $\rho_x = \rho_4$. For chamber approach $\rho_x = \rho_5$. and β may be taken as zero. A simplified approximation suitable for the range of temperatures from 40°F to 100°F is

$$Re = 1,363,000 \, D_6 \sqrt{\frac{\Delta P \rho_x}{1 - \beta^4}}.$$

This is based on $C = 0.95$, $Y = 0.96$, $E = 1.0$, and $\mu = 1.222 \times 10^{-5}$ lbm/ft-s.

9.3.2.6 Discharge Coefficient. The nozzle discharge coefficient (C) shall be determined from Figure 18, Table 3, or

$$C = 0.9986 - \frac{7.006}{\sqrt{Re}} + \frac{134.6}{Re} \ for \ \frac{L}{D} = 0.6 \ or$$

$$C = 0.9986 - \frac{6.688}{\sqrt{Re}} + \frac{131.5}{Re} \ for \ \frac{L}{D} = 0.5$$

for Re of 12,000 and above [14].

9.3.2.7 Flow Rate for Ducted Nozzle. The volume flow rate (Q_4) at the entrance to a ducted nozzle shall be calculated from

$$Q_4 = \frac{1096 C A_6 Y \sqrt{\Delta P / \rho_4}}{\sqrt{1 - E\beta^4}}.$$

The area (A_6) is measured at the plane of the throat taps.

9.3.2.8 Flow Rate for Chamber Nozzles. The volume flow rate (Q_5) at the entrance to a nozzle or multiple nozzles with chamber approach shall be calculated from

$$Q_5 = 1096 Y \sqrt{\Delta P / \rho_5} \, \Sigma(CA_6).$$

The coefficient (C) and area (A_6) must be determined for each nozzle and their products summed as indicated. The area (A_6) is measured at the plane of the throat taps or the nozzle exit for nozzles without throat taps.

9.3.2.9 Fan Flow Rate. The fan flow rate (Q) at test conditions shall be obtained from the equation of continuity,

$$Q = Q_x(\rho_x/\rho)$$

where Plane x is either Plane 4 or Plane 5 as appropriate.

9.4 Fan Velocity Pressure at Test Conditions

9.4.1 Pitot Traverse. When Pitot traverse measurements are made, the fan velocity pressure (P_v) shall be determined from the velocity pressure (P_{v3}) using

$$P_v = P_{v3}\left(\frac{\rho_3}{\rho_2}\right)\left(\frac{A_3}{A_2}\right)^2.$$

Whenever P_{s3} and P_{s2} differ by less than 4 in. wg, ρ_3 may be considered equal to ρ_2.

9.4.2 Nozzle. When flow rate is determined from nozzle measurements, the fan velocity pressure (P_v) shall be calculated from the velocity (V_2) and density (ρ_2) at the fan outlet using

$$Q_2 = Q(\rho/\rho_2),$$
$$V_2 = Q_2/A_2, \text{ and}$$
$$P_v = (V_2/1096)^2\rho_2, \text{ or}$$
$$P_v = \left(\frac{Q\rho}{1096A_2}\right)^2\frac{1}{\rho_2}.$$

9.5 Fan Total Pressure at Test Conditions.

The fan total pressure shall be calculated from measurements of pressures in ducts or chambers corrected for pressure losses in measuring ducts which occur between the fan and the measuring stations.

9.5.1 Averages. Certain averages shall be calculated from measurements as follows:

9.5.1.1 Pitot Traverse. When a Pitot traverse is used for pressure measurement: the average velocity pressure (P_{v3}) shall be as determined in 9.3.1.1, the average velocity (V_3) shall be as determined in 9.3.1.2, and the average static pressure (P_{s3}) shall be calculated from

$$P_{s3} = \frac{\Sigma P_{s3r}}{n}.$$

9.5.1.2 Duct Piezometer. When a duct piezometer is used for pressure measurement: the average static pressure (P_{s4}) shall be the measured value (P_{s4r}), the average velocity (V_4) shall be calculated from the flow rate (Q) as determined in 9.3.2.9, and

$$V_4 = \left(\frac{Q}{A_4}\right)\left(\frac{\rho}{\rho_4}\right),$$

and the average velocity pressure (P_{v4}) shall be calculated from

$$P_{v4} = \left(\frac{V_4}{1096}\right)^2\rho_4.$$

9.5.1.3 Chamber. When a chamber piezometer or total pressure tube is used for pressure measurement, the average static pressure (P_{s7}) shall be the measured value (P_{s7r}) and the average total pressure (P_{t8}) shall be the measured value (P_{t8r}).

9.5.2 Pressure Losses. Pressure losses shall be calculated for measuring ducts and straighteners which are located between the fan and the measuring station.

9.5.2.1 Hydraulic Diameter. The hydraulic diameter for round ducts is the actual diameter (D). The hydraulic diameter for rectangular ducts shall be calculated from the inside traverse dimensions a and b using $D_h = 2 ab / (a + b)$.

9.5.2.2 Reynolds Number. The Reynolds number (Re) based on the hydraulic diameter (D_h) in ft shall be calculated from

$$Re = \frac{D_h V\rho}{60\mu}$$

using properties of air as determined in 9.2 and the appropriate velocity (V) in fpm.

9.5.2.3 Coefficient of Friction. The coefficient of friction (f) shall be determined from Figure 19 [27] or from

$$f = 0.14 \ Re^{0.17}.$$

9.5.2.4 Equivalent Length. The ratio of equivalent length of a straightener (L_e) to hydraulic diameter (D_h) shall be determined from Table 4 [27] using the element thickness (y) and equivalent diameter (D) or from

$$\frac{L_e}{D_h} = \frac{15.04}{[1 - 26.65(y/D) + 184.6(y/D)^2]^{1.83}}.$$

This expression is exact for round duct straighteners and sufficiently accurate for rectangular duct straighteners.

9.5.3 Inlet Total Pressure. The total pressure at the fan inlet (P_{t1}) shall be calculated as follows:

9.5.3.1 Open Inlet. When the fan draws directly from atmosphere, P_{t1} shall be considered equal to atmospheric pressure, which is zero gauge, so that

$$P_{t1} = 0.$$

9.5.3.2 Inlet Chamber. When the fan is connected to an inlet chamber, P_{t1} shall be considered equal to the chamber pressure (P_{t5}), so that

$$P_{t1} = P_{t5}.$$

9.5.3.3 Inlet Duct. When the fan is connected to an inlet duct, P_{t1} shall be considered equal to the algebraic sum of the average static pressure (P_{s3}) and the average velocity pressure (P_{v3}) corrected for the friction due to the length of duct (L_1) between the measuring station and the fan, so that

$$P_{t1} = P_{s3} + P_{v3} - f\frac{L_{1,3}}{D_{h3}}P_{v3}.$$

Pressure P_{s3} will be less than atmospheric and its value will be negative.

9.5.4 Outlet Total Pressure. The total pressure at the fan outlet (P_{t2}) shall be calculated as follows:

9.5.4.1 Open Outlet. When the fan discharges directly to atmosphere, the static pressure at the outlet (P_{s2}) shall be considered equal to atmospheric pressure, which is zero gauge, so that

$$P_{t2} = P_{s2} + P_{v2} = P_{v2}.$$

The value of P_{v2} shall be as determined in 9.4.

9.5.4.2 Outlet Chamber. When the fan discharges directly into an outlet chamber, the static pressure at the outlet (P_{s2}) shall be considered equal to the average chamber pressure (P_{s7}), so that

$$P_{t2} = P_{s2} + P_{v2} = P_{s7} + P_{v2}.$$

The value of P_{v2} shall be as determined in 9.4.

9.5.4.3 Short Duct. When the fan discharges through an outlet duct without a measuring station either to atmosphere or into an outlet chamber, the pressure loss of the duct shall be considered zero and calculations made according to 9.5.4.1 or 9.5.4.2.

9.5.4.4 Piezometer Outlet Duct. When the fan discharges into a duct with a piezometer ring, P_{t2} shall be considered equal to the sum of the average static pressure (P_{s4}) and the average velocity pressure (P_{v4}) corrected for the friction due to both the equivalent length of the straightener (L_e) and the length of duct $(L_{2,4})$ between the fan and the measuring station, so that

$$P_{t2} = P_{s4} + P_{v4} + f\left(\frac{L_{2,4}}{D_{h4}} + \frac{L_e}{D_{h4}}\right)P_{v4}.$$

9.5.4.5 Pitot Outlet Duct. When the fan discharges into a duct with a Pitot traverse, P_{t2} shall be considered equal to the sum of the average static pressure (P_{s3}) and the average velocity pressure (P_{v3}) corrected for the friction due to both the equivalent length of the straightener (L_e) and the length of duct $(L_{2,3})$ between the fan and the measuring station, so that

$$P_{t2} = P_{s3} + P_{v3} + f\left(\frac{L_{2,3}}{D_{h3}} + \frac{L_e}{D_{h3}}\right)P_{v3}.$$

9.5.5 Fan Total Pressure. The fan total pressure (P_t) shall be calculated from

$$P_t = P_{t2} - P_{t1}.$$

This is an algebraic expression so that if P_{t1} is negative, P_t will be numerically greater than P_{t2}.

9.6 Fan Static Pressure at Test Conditions. The fan static pressure (P_s) shall be calculated from

$$P_s = P_t - P_{v2}.$$

9.7 Fan Power Input at Test Conditions.

9.7.1 Reaction Dynamometer. When a reaction dynamometer is used to measure torque, the fan power input (H) shall be calculated from the beam load (F), the moment arm (l), and the fan speed (N) using

$$H = \frac{2\pi FlN}{33000 \times 12}.$$

9.7.2 Torsion Element. When a torsion element is used to measure torque, the fan power input (H) shall be calculated from the torque (T) and the speed (N) using

$$H = \frac{2\pi TN}{33000 \times 12}.$$

9.7.3 Calibrated Motor. When a calibrated electric motor is used to measure input, the fan power input (H) may be calculated from the power input to the motor (W) and the motor efficiency (η) using

$$H = \frac{W\eta}{745.7}.$$

9.8 Fan Efficiency

9.8.1 Fan Power Output.
The fan power output (H_o) would be proportional to the product of fan flow rate (Q) and fan total pressure (P_t) if air were incompressible. Since air is compressible, thermodynamic effects influence output and a compressibility coefficient (K_p) must be applied making output proportional to $Q P_t K_p$ [28].

$$H_o = Q P_t K_p / 6362.$$

9.8.2 Compressibility Factor.
The compressibility coefficient (K_p) may be determined from

$$x = \frac{P_t}{P_{tl} + 13.63 p_b} \text{ and}$$

$$z = \left(\frac{\gamma - 1}{\gamma}\right)\left(\frac{6362 H/Q}{P_{tl} + 13.63 p_b}\right)$$

using Figure 20 or from

$$K_p = \left(\frac{ln(1 + x)}{x}\right)\left(\frac{z}{ln(1 + z)}\right)$$

which may be evaluated directly or with the aid of Table 5 values [28]. P_t, P_{tl}, p_b, H, and Q are all test values. The isentropic exponent (γ) may be taken as 1.400 for air. If the fan total pressure is less than 12 in. wg, the value of K_p will usually be greater than 0.99 in which case the value of K_p may be taken as unity.

9.8.3 Fan Total Efficiency.
The fan total efficiency (η_t) is the ratio of fan power output to fan power input or

$$\eta_t = \frac{Q P_t K_p}{6362 H}.$$

9.8.4 Fan Static Efficiency.
The fan static efficiency (η_s) may be calculated from the fan total efficiency (η_t) and the ratio of fan static pressure to fan total pressure using

$$\eta_s = \eta_t (P_s / P_t).$$

9.9 Conversions to Nominal Constant Values of Density and Speed.
During a laboratory test, the air density and speed of rotation may vary slightly from one determination to another. It may be desirable to convert the results calculated for test conditions to those that would prevail at nominal constant density, nominal constant speed, or both. This may be done provided the nominal constant density (ρ_c) is within 10% of the actual density (ρ) and the nominal constant speed (N_c) is within 5% of the actual speed (N).

9.9.1 Compressibility Factor Ratio.
In order to make the conversions it is necessary to determine the ratio of the compressibility coefficient for actual conditions to that for nominal conditions (K_p/K_{pc}). This can be accomplished using previously calculated values of x and z for actual conditions as follows:

$$\frac{z}{z_c} = \left(\frac{P_{tlc} + 13.63 p_{bc}}{P_{tl} + 13.63 p_b}\right)\left(\frac{\rho}{\rho_c}\right)\left(\frac{N}{N_c}\right)^2\left(\frac{\gamma_c}{\gamma_c - 1}\right)\left(\frac{\gamma - 1}{\gamma}\right),$$

(Since the ratios of specific heats γ_c and γ are equal for air at laboratory conditions the last two factors may be omitted in this and the following equations.)

$$z_c = z / (z/z_c),$$

$$ln(1 + x_c) = ln(1 + x)\left(\frac{ln(1 + z_c)}{ln(1 + z)}\right)\left(\frac{\gamma - 1}{\gamma}\right)\left(\frac{\gamma_c}{\gamma_c - 1}\right),$$

$$x_c = e^{ln(1 + x_c)} - 1, \text{ and}$$

$$\frac{K_p}{K_{pc}} = \left(\frac{z}{z_c}\right)\left(\frac{x_c}{x}\right)\left(\frac{\gamma_c}{\gamma - 1}\right)\left(\frac{\gamma_c - 1}{\gamma_c}\right).$$

If K_p/K_{pc} is between 0.99 and 1.01, it may be taken as unity. Table 6 may be used to determine $ln(1 + x)$ or $ln(1 + z)$ and their antilogs.

9.9.2 Conversion Formulae.
Actual test results may be converted to nominal test results using the following [28]:

$$Q_c = Q\left(\frac{N_c}{N}\right)\left(\frac{K_p}{K_{pc}}\right),$$

$$P_{tc} = P_t\left(\frac{N_c}{N}\right)^2\left(\frac{\rho_c}{\rho}\right)\left(\frac{K_p}{K_{pc}}\right),$$

$$P_{vc} = P_v\left(\frac{N_c}{N}\right)^2\left(\frac{\rho_c}{\rho}\right),$$

$$P_{sc} = P_{tc} - P_{vc},$$

$$H_c = H\left(\frac{N_c}{N}\right)^3\left(\frac{\rho_c}{\rho}\right)\left(\frac{K_p}{K_{pc}}\right),$$

$$\eta_{tc} = \eta_t, \text{ and}$$

$$\eta_{sc} = \eta_{tc}\left(\frac{P_{sc}}{P_{tc}}\right).$$

10. Report and Results of Test

10.1 Report. The report of a laboratory fan test shall include object, results, test data, and descriptions of the test fan including appurtenances, test setup, and test instruments as outlined in Section 8. The laboratory shall be identified by name and location.

10.2 Performance Curves. The results of a fan test shall be presented as performance curves. Typical fan performance curves are shown in Figure 21.

10.2.1 Coordinates. Performance curves shall be drawn with fan flow rate as abscissa. Fan pressure and fan power input shall be plotted as ordinates. Fan total pressure, fan static pressure, or both may be shown. If all results were obtained at the same speed or if results were converted to a nominal speed, such speed shall be listed; otherwise a curve with fan speed as ordinate shall be drawn. If all results were obtained at the same air density or if results were converted to a nominal density, such density shall be listed; otherwise a curve with fan air density as ordinate shall be drawn. Curves with fan total efficiency or fan static efficiency as ordinates may be drawn. Barometric pressure shall be listed when fan pressures exceed 10 in. wg.

10.2.2 Test Points. The results for each determination shall be shown on the performance curve as a series of circled points, one for each variable plotted as ordinate.

10.2.3 Curve-Fitting. Curves for each variable shall be obtained by drawing a curve or curves using the test points for reference. The curves shall not depart from the test points by more than 0.5% of any test value and the sum of the deviations shall approximate zero.

10.2.4 Discontinuities. When discontinuities exist they shall be identified with a broken line. If equilibrium cannot be established for any determination, the curves joining the points for that determination with adjacent points shall be drawn as broken lines.

10.2.5 Identification. Performance curve sheets shall list the test fan and test setup. Sufficient details shall be listed to identify clearly the fan and setup. Otherwise, a report containing such information shall be referenced.

Table 1   Psychrometric Density Table

Dry-Bulb Temp. °F	Density of Saturated Air for Various Barometric and Hygrometric Conditions—lbm/ft³						Increase in Density Per 0.1 in. Hg Rise in Barometer	Approx. Average Increase in Density Per °F Wet-Bulb Depression t_d-t_w
	Barometric Pressure in. Hg							
	28.5	29.0	29.5	30.0	30.5	31.0		
30	.07703	.07839	.07974	.08110	.08245	.08380	.00027	.000017
31	.07687	.07822	.07957	.08093	.08228	.08363	.00027	.000017
32	.07671	.07806	.07940	.09075	.08210	.08345	.00027	.000017
33	.07654	.07789	.07924	.08058	.08193	.08327	.00027	.000018
34	.07638	.07772	.07907	.08041	.08175	.08310	.00027	.000018
35	.07621	.07756	.07890	.08024	.08158	.08292	.00027	.000018
36	.07605	.07739	.07873	.08007	.08141	.08274	.00027	.000018
37	.07589	.07723	.07856	.07990	.08123	.08257	.00027	.000019
38	.07573	.07706	.07840	.07973	.08106	.08239	.00027	.000019
39	.07557	.07690	.07823	.07956	.08089	.08222	.00027	.000019
40	.07541	.07674	.07806	.07939	.08072	.08205	.00027	.000019
41	.07525	.07657	.07790	.07922	.08055	.08187	.00026	.000020
42	.07509	.07641	.07773	.07905	.08038	.08170	.00026	.000020
43	.07493	.07625	.07757	.07889	.08021	.08153	.00026	.000020
44	.07477	.07609	.07740	.07872	.08004	.08135	.00026	.000020
45	.07461	.07592	.07724	.07855	.07986	.08118	.00026	.000020
46	.07445	.07576	.07707	.07838	.07970	.08101	.00026	.000021
47	.07429	.07560	.07691	.07822	.07953	.08084	.00026	.000021
48	.07413	.07544	.07674	.07805	.07936	.08066	.00026	.000021
49	.07397	.07528	.07658	.07788	.07919	.08049	.00026	.000022
50	.07381	.07512	.07642	.07772	.07902	.08032	.00026	.000022
51	.07366	.07496	.07625	.07755	.07885	.08015	.00026	.000022
52	.07350	.07479	.07609	.07739	.07868	.07998	.00026	.000023
53	.07334	.07464	.07593	.07722	.07852	.07981	.00026	.000023
54	.07318	.07447	.07576	.07706	.07835	.07964	.00026	.000023
55	.07302	.07431	.07560	.07689	.07818	.07947	.00026	.000024
56	.07287	.07415	.07544	.07673	.07801	.07930	.00026	.000024
57	.07271	.07399	.07528	.07656	.07784	.07913	.00026	.000025
58	.07255	.07383	.07512	.07640	.07768	.07896	.00026	.000025
59	.07240	.07367	.07495	.07623	.07751	.07879	.00026	.000025
60	.07224	.07352	.07479	.07607	.07734	.07862	.00026	.000026
61	.07208	.07336	.07463	.07590	.07718	.07845	.00026	.000026
62	.07193	.07320	.07447	.07574	.07701	.07828	.00026	.000027
63	.07177	.07304	.07430	.07557	.07684	.07811	.00026	.000027
64	.07161	.07288	.07414	.07541	.07668	.07794	.00026	.000028

Note: Approx. average decrease in density per 0.1°F rise in dry-bulb temperature equals .000017 lbm/ft³.

Table 1   Psychrometric Density Table

Dry-Bulb Temp. F	Density of Saturated Air for Various Barometric and Hygrometric Conditions—lbm ft³ Barometric Pressure in. Hg						Increase in Density Per 0.1 in. Hg Rise in Barometer	Approx. Average Increase in Density Per F Wet-Bulb Depression $t_d - t_w$
	28.5	**29.0**	**29.5**	**30.0**	**30.5**	**31.0**		
65	.07145	.07272	.07398	.07525	.07651	.07777	.00026	.000028
66	.07130	.07256	.07382	.07508	.07634	.07760	.00026	.000029
67	.07114	.07240	.07366	.07492	.07618	.07744	.00026	.000029
68	.07098	.07224	.07350	.07475	.07601	.07727	.00026	.000030
69	.07083	.07208	.07333	.07459	.07584	.07710	.00026	.000030
70	.07067	.07192	.07317	.07442	.07568	.07693	.00026	.000031
71	.07051	.07176	.07301	.07426	.07551	.07676	.00025	.000031
72	.07035	.07160	.07285	.07410	.07534	.07659	.00025	.000032
73	.07020	.07144	.07268	.07393	.07517	.07642	.00025	.000033
74	.07004	.07128	.07252	.07377	.07501	.07625	.00025	.000033
75	.06988	.07112	.07236	.07360	.07484	.07608	.00025	.000034
76	.06972	.07096	.07220	.07343	.07467	.07591	.00025	.000034
77	.06956	.07080	.07203	.07327	.07451	.07574	.00025	.000035
78	.06940	.07064	.07187	.07310	.07434	.07557	.00025	.000036
79	.06925	.07048	.07171	.07294	.07417	.07540	.00025	.000036
80	.06909	.07032	.07155	.07277	.07400	.07523	.00025	.000037
81	.06893	.07015	.07138	.07261	.07383	.07506	.00025	.000038
82	.06877	.07000	.07122	.07244	.07366	.07189	.00024	.000039
83	.06861	.06983	.07105	.07227	.07349	.07472	.00024	.000039
84	.06845	.06967	.07089	.07211	.07333	.07154	.00024	.000040
85	.06829	.06950	.07072	.07194	.07316	.07437	.00024	.000041
86	.06812	.06934	.07056	.07177	.07299	.07420	.00024	.000042
87	.06796	.06917	.07039	.07160	.07281	.07403	.00024	.000043
88	.06780	.06901	.07022	.07143	.07264	.07385	.00024	.000043
89	.06764	.06885	.07005	.07126	.07247	.07368	.00024	.000044
90	.06748	.06868	.06989	.07109	.07230	.07351	.00024	.000045
91	.06731	.06852	.06972	.07092	.07213	.07333	.00024	.000046
92	.06715	.06835	.06955	.07075	.07195	.07316	.00024	.000047
93	.06698	.06818	.06938	.07058	.07178	.07298	.00024	.000048
94	.06682	.06801	.06921	.07041	.07161	.07280	.00024	.000049
95	.06665	.06785	.06904	.07024	.07143	.07263	.00024	.000050
96	.06648	.06768	.06887	.07006	.07126	.07245	.00024	.000051
97	.06632	.06751	.06870	.06989	.07108	.07227	.00024	.000052
98	.06615	.06734	.06853	.06972	.07091	.07209	.00024	.000053
99	.06598	.06717	.06835	.06954	.07073	.07191	.00024	.000054
100	.06581	.06700	.06818	.06937	.07055	.07174	.00024	.000055

Note: Approx. average decrease in density per 0.1°F rise in dry-bulb temperature equals .000017 lbm ft³.

Table 2 Expansion Factors (Y) for Nozzles

Static Pressure Ratio (α)	Diameter Ratio (β)					
	0	0.20	0.25	0.30	0.40	0.50
1.00	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
0.98	0.98923	0.98921	0.98917	0.98911	0.98886	0.98829
0.96	0.97834	0.97829	0.97823	0.97811	0.97761	0.97650
0.94	0.96732	0.96726	0.96716	0.96699	0.96625	0.96461
0.92	0.95619	0.95610	0.95598	0.95575	0.95478	0.95263
0.90	0.94492	0.94481	0.94466	0.94438	0.94319	0.94055

Table 3 Discharge Coefficients for Nozzles

Nozzle Discharge Coefficient (C)	Reynolds Number (Re)		Nozzle Discharge Coefficient (C)	Reynolds Number (Re)	
	L/D = 0.5	L/D = 0.6		L/D = 0.5	L/D = 0.6
0.950	12961	14720	0.973	57519	63948
			0.974	62766	69736
0.951	13657	15491			
0.952	14401	16314	0.975	68713	76295
0.953	15196	17195	0.976	75488	83765
0.954	16047	18137	0.977	83249	92320
			0.978	92195	102180
0.955	16961	19148	0.979	102576	113620
0.956	17942	20234			
0.957	18998	21402	0.980	114715	126992
0.958	20136	22661	0.981	129024	142753
0.959	21365	24021	0.982	146048	161500
			0.983	166513	184032
0.960	22695	25492	0.984	191401	211428
0.961	24137	27086			
0.962	25703	28817	0.985	222073	245182
0.963	27407	30701	0.986	260450	287409
0.964	29268	32758	0.987	309324	341172
			0.988	372865	411057
0.965	31303	35006	0.989	457538	504164
0.966	33535	37472			
0.967	35989	40184	0.990	573788	631966
0.968	38697	43174	0.991	739389	813986
0.969	41693	46482	0.992	986593	1085643
			0.993	1378954	1516727
0.970	45018	50153	0.994	2056291	2260760
0.971	48723	54242	0.995	3377887	3712194
0.972	52866	58815			

Table 4 Equivalent Lengths of Straighteners

$\dfrac{y}{D}$	$\dfrac{L_e}{D}$
0	15.0
0.001	15.8
0.002	16.6
0.003	17.5
0.004	18.4
0.005	19.4

Table 5 $[ln(1 + x)]/x$ or $[ln(1 + z)]/z$

x or z	0.000	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009	Diff.
0.00	1.00000	0.99950	0.99900	0.99850	0.99801	0.99751	0.99701	0.99652	0.99602	0.99553	0.00050
0.01	0.99503	0.99454	0.99405	0.99356	0.99306	0.99257	0.99208	0.99160	0.99111	0.99062	0.00049
0.02	0.99013	0.98964	0.98916	0.98867	0.98819	0.98770	0.98722	0.98674	0.98626	0.98577	0.00049
0.03	0.98529	0.98481	0.98433	0.98385	0.98338	0.98290	0.98242	0.98194	0.98147	0.98099	0.00048
0.04	0.98052	0.98004	0.97957	0.97910	0.97862	0.97815	0.97768	0.97721	0.97674	0.97627	0.00047
0.05	0.97580	0.97534	0.97487	0.97440	0.97393	0.97347	0.97300	0.97254	0.97207	0.97161	0.00046
0.06	0.97115	0.97069	0.97022	0.96976	0.96930	0.96884	0.96838	0.96792	0.96747	0.96701	0.00046
0.07	0.96655	0.96610	0.96564	0.96518	0.96473	0.96428	0.96382	0.96337	0.96292	0.96246	0.00045
0.08	0.96201	0.96156	0.96111	0.96066	0.96021	0.95976	0.95932	0.95887	0.95842	0.95798	0.00044
0.09	0.95753	0.95708	0.95664	0.95620	0.95575	0.95531	0.95487	0.95442	0.95398	0.95354	0.00044
0.10	0.95310	0.95266	0.95222	0.95178	0.95135	0.95091	0.95047	0.95003	0.94960	0.94916	0.00044
0.11	0.94873	0.94829	0.94786	0.94743	0.94699	0.94656	0.94613	0.94570	0.94527	0.94484	0.00043
0.12	0.94441	0.94398	0.94355	0.94312	0.94269	0.94226	0.94184	0.94141	0.94099	0.94056	0.00043
0.13	0.94014	0.93971	0.93929	0.93886	0.93844	0.93802	0.93760	0.93718	0.93676	0.93634	0.00042
0.14	0.93592	0.93550	0.93508	0.93466	0.93424	0.93383	0.93341	0.93299	0.93258	0.93216	0.00041
0.15	0.93175	0.93133	0.93092	0.93050	0.93009	0.92968	0.92927	0.92886	0.92845	0.92803	0.00041
0.16	0.92763	0.92722	0.92681	0.92640	0.92599	0.92558	0.92518	0.92477	0.92436	0.92396	0.00041
0.17	0.92355	0.92315	0.92274	0.92234	0.92194	0.92153	0.92113	0.92073	0.92033	0.91993	0.00041
0.18	0.91952	0.91912	0.91872	0.91833	0.91793	0.91753	0.91713	0.91673	0.91634	0.91594	0.00040
0.19	0.91554	0.91515	0.91475	0.91436	0.91396	0.91357	0.91318	0.91278	0.91239	0.91200	0.00039
0.20	0.91161	0.91122	0.91083	0.91044	0.91005	0.90966	0.90927	0.90888	0.90849	0.90810	0.00039
0.21	0.90772	0.90733	0.90694	0.90656	0.90617	0.90579	0.90540	0.90502	0.90463	0.90425	0.00038
0.22	0.90387	0.90349	0.90310	0.90272	0.90234	0.90196	0.90158	0.90120	0.90082	0.90044	0.00038
0.23	0.90006	0.89968	0.89931	0.89893	0.89855	0.89817	0.89780	0.89742	0.89705	0.89667	0.00038
0.24	0.89630	0.89592	0.89555	0.89518	0.89480	0.89443	0.89406	0.89369	0.89332	0.89294	0.00037

Table 6 $ln(1 + x)$ or $ln(1 + z)$

x or z	0.000	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009	Diff.
0.00	0.00000	0.00100	0.00200	0.00300	0.00399	0.00499	0.00598	0.00698	0.00797	0.00896	0.00100
0.01	0.00995	0.01094	0.01193	0.01292	0.01390	0.01489	0.01587	0.01686	0.01784	0.01882	0.00099
0.02	0.01980	0.02078	0.02176	0.02274	0.02372	0.02469	0.02567	0.02664	0.02762	0.02859	0.00097
0.03	0.02956	0.03053	0.03150	0.03247	0.03343	0.03440	0.03537	0.03633	0.03730	0.03826	0.00097
0.04	0.03922	0.04018	0.04114	0.04210	0.04306	0.04402	0.04497	0.04593	0.04688	0.04784	0.00096
0.05	0.04879	0.04974	0.05069	0.05164	0.05259	0.05354	0.05449	0.05543	0.05638	0.05733	0.00095
0.06	0.05827	0.05921	0.06015	0.06110	0.06204	0.06297	0.06391	0.06185	0.06579	0.06672	0.00093
0.07	0.06766	0.06859	0.06953	0.07046	0.07139	0.07232	0.07325	0.07418	0.07511	0.07603	0.00093
0.08	0.07696	0.07789	0.07881	0.07973	0.08066	0.08158	0.08250	0.08342	0.08434	0.08526	0.00092
0.09	0.08618	0.08709	0.08801	0.08893	0.08984	0.09075	0.09167	0.09258	0.09349	0.09440	0.00091
0.10	0.09531	0.09622	0.09713	0.09803	0.09894	0.09985	0.10075	0.10165	0.10256	0.10346	0.00090
0.11	0.10436	0.10526	0.10616	0.10706	0.10796	0.10885	0.10975	0.11065	0.11154	0.11244	0.00089
0.12	0.11333	0.11422	0.11511	0.11600	0.11689	0.11778	0.11867	0.11956	0.12045	0.12133	0.00089
0.13	0.12222	0.12310	0.12399	0.12487	0.12575	0.12663	0.12751	0.12839	0.12927	0.13015	0.00088
0.14	0.13103	0.13191	0.13278	0.13366	0.13453	0.13540	0.13628	0.13715	0.13802	0.13889	0.00087
0.15	0.13976	0.14063	0.14150	0.14237	0.14323	0.14410	0.14497	0.14583	0.14669	0.14756	0.00087
0.16	0.14842	0.14928	0.15014	0.15100	0.15186	0.15272	0.15358	0.15444	0.15529	0.15615	0.00086
0.17	0.15700	0.15786	0.15871	0.15956	0.16042	0.16127	0.16212	0.16297	0.16382	0.16467	0.00085
0.18	0.16551	0.16636	0.16721	0.16805	0.16890	0.16974	0.17059	0.17143	0.17227	0.17311	0.00084
0.19	0.17395	0.17479	0.17563	0.17647	0.17731	0.17815	0.17898	0.17982	0.18065	0.18149	0.00084
0.20	0.18232	0.18315	0.18399	0.18482	0.18565	0.18648	0.18731	0.18814	0.18897	0.18979	0.00083
0.21	0.19062	0.19145	0.19227	0.19310	0.19392	0.19474	0.19557	0.19639	0.19721	0.19803	0.00082
0.22	0.19885	0.19967	0.20049	0.20131	0.20212	0.20294	0.20376	0.20457	0.20539	0.20620	0.00082
0.23	0.20701	0.20783	0.20864	0.20945	0.21026	0.21107	0.21188	0.21269	0.21350	0.21430	0.00081
0.24	0.21511	0.21592	0.21672	0.21753	0.21833	0.21914	0.21994	0.22074	0.22154	0.22234	0.00081

$+0.00$ D
-0.03
D

0.25D

L

D

0.667D

$+0.00$ D
-0.03
D

L

D

0.667D

FAIRING RADIUS
ABOUT 0.05 D
IF NECESSARY.

FAIRING RADIUS
ABOUT 0.05 D
IF NECESSARY.
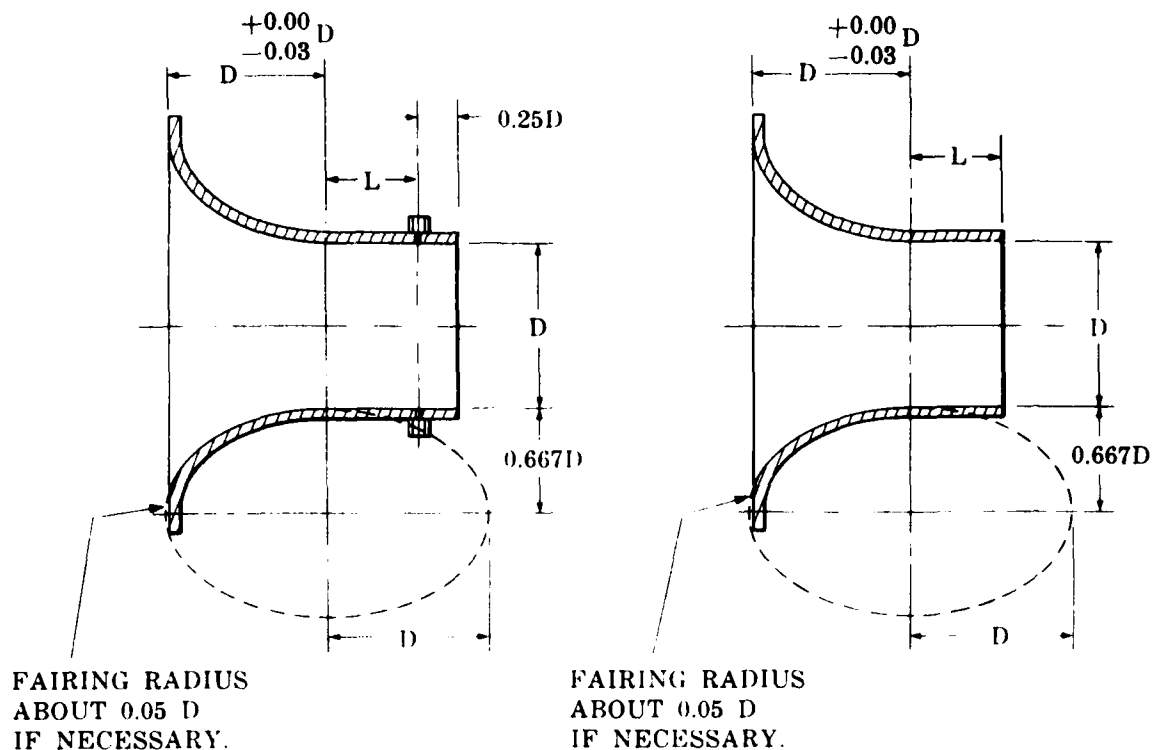
NOZZLE WITH THROAT TAPS   NOZZLE WITHOUT THROAT TAPS

NOTES

1. Nozzle throat dimension L shall be either 0.6D ⁺ 0.005D (recommended) or 0.5D ⁺ 0.005D.

2. Nozzle shall have elliptical section as shown. Two and three radii approximations to the elliptical form that do not differ at any point in the normal direction more than 1.5⁺ D from the elliptical form may be used. The outlet edge of the nozzle shall be square, sharp, and free from burrs, nicks or roundings.

3. The nozzle throat shall be measured (to an accuracy of 0.001 D) at the minor axis of the ellipse and the nozzle exit. At each place, four diameters—approximately 45 apart must be within ⁺ 0.002 D of the mean. At the entrance to the throat the mean may be 0.002 D greater, but no less than the mean at the nozzle exit.

4. The nozzle surface shall fair smoothly so that a straight-edge may be rocked over the surface without clicking and the surface waves shall not be greater than 0.001 D peak to peak.

5. When nozzles are used in a chamber, either of the types shown above may be used. Where a nozzle discharges directly to a duct, nozzles with throat taps shall be used, and the nozzle outlet should be flanged.

6. Throat tap nozzles shall have four static pressure taps 90° apart connected to a piezometer ring.

Figure 4   Nozzles

SECTION A-A
(CONVERGING SECTION)

SECTION B-B
(DIVERGING SECTION)
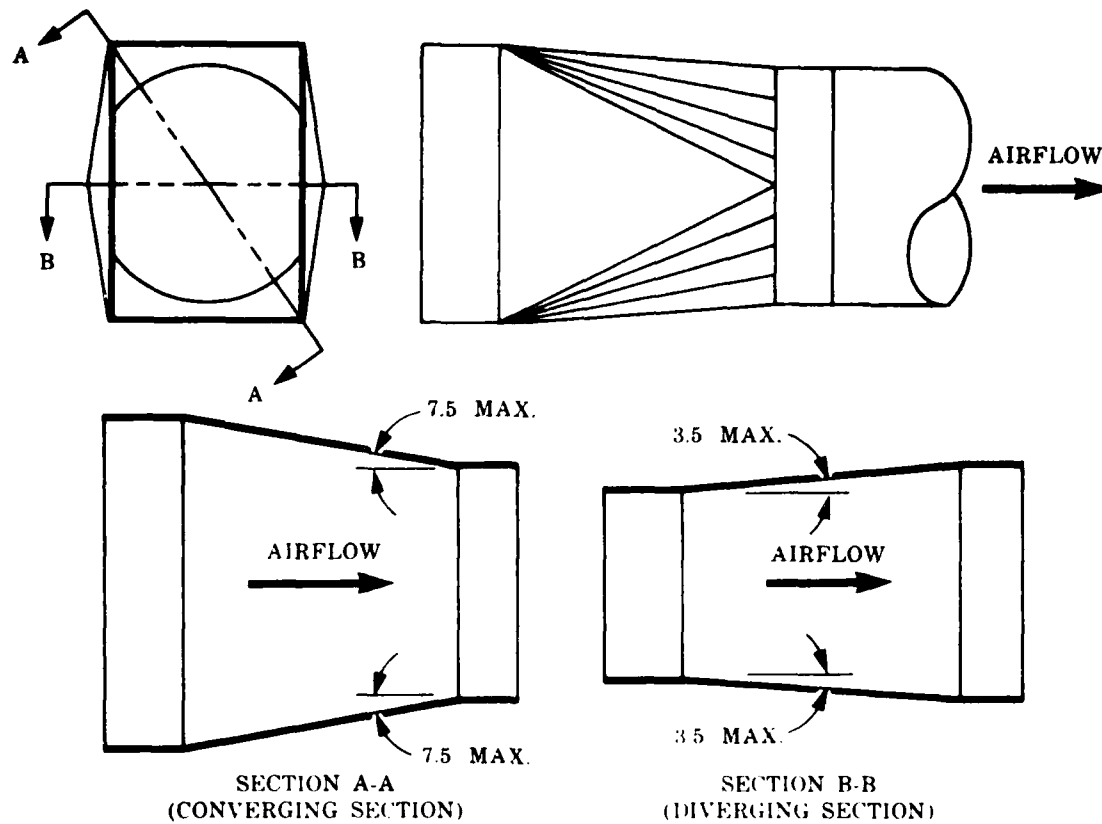
Figure 5   Transformation Piece

NOTE: All Dimensions shall be within ± 0.005D
except y which shall not exceed 0.005D.

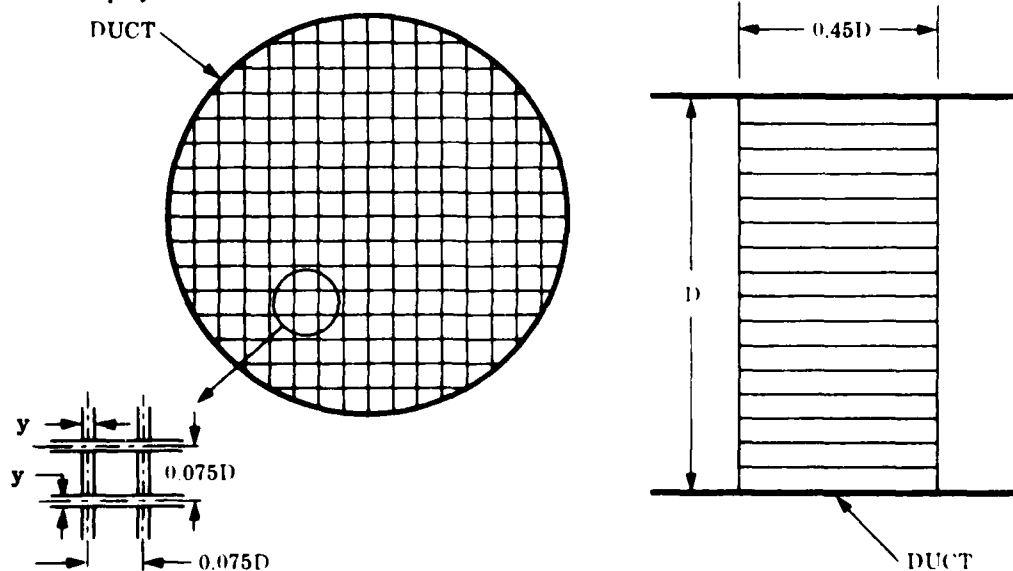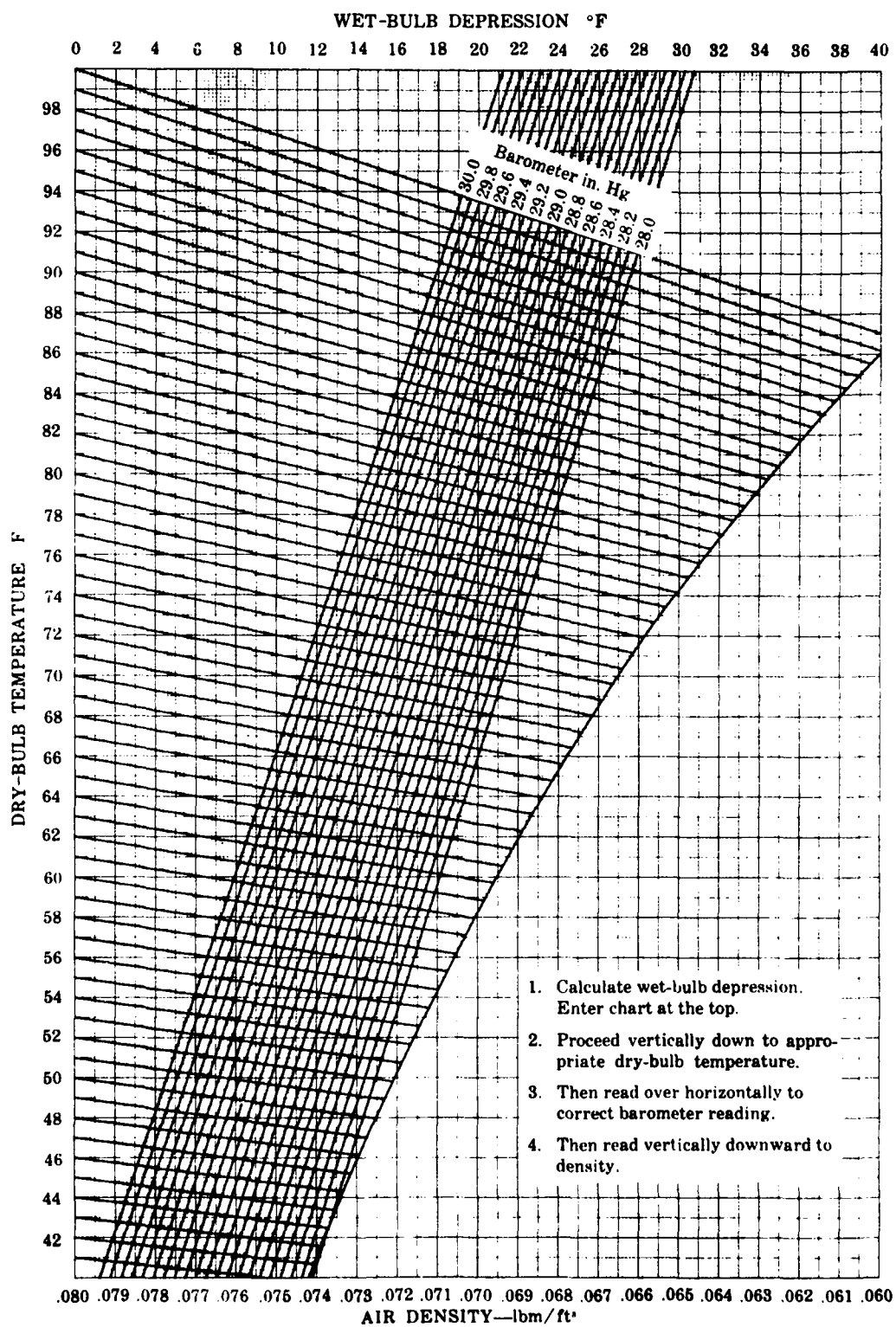**Figure 6   Flow Straightener**

PL.1 PL.2   PL.7   PL.5 PL.6

* See note 6

P_{s7} P_{s5} ΔP

SETTLING
MEANS

SETTLING MEANS
(see note 5)

VARIABLE
EXHAUST
SYSTEM

FLOW AND PRESSURE FORMULAE

$$Q_s = 1096\, Y\sqrt{\Delta P/\rho_5}\, \Sigma(CA_6)$$

$$Q = Q_s \left(\frac{\rho_5}{\rho}\right)$$

$$V_2 = \left(\frac{Q}{A_2}\right)\left(\frac{\rho}{\rho_2}\right)$$

$$P_{v2} = \left(\frac{V_2}{1096}\right)^2 \rho_2$$

$$P_v = P_{v2}$$

$$P_{t1} = 0$$

$$P_{t2} = P_{s7} + P_v$$

$$P_t = P_{t2} - P_{t1}$$

$$P_s = P_t - P_v$$

NOTES

1. Dotted lines on fan inlet indicate an inlet bell which may be used to simulate an inlet duct. The inlet bell friction shall not be considered.

2. Dotted lines on fan outlet indicate a uniform duct 2 to 3 equivalent diameters long and of an area within ± 0.5% of the fan outlet area and a shape to fit the fan outlet. This may be used to simulate an outlet duct. The outlet duct friction shall not be considered.

3. The fan may be tested without outlet duct in which case it shall be mounted on the end of the chamber.

4. Variable exhaust system may be an auxiliary fan or a throttling device.

5. The distance from the exit face of the largest nozzle to the downstream settling means shall be a minimum of 2.5 throat diameters of the largest nozzle.

6. Dimension J shall be at least 1.0 times the fan equivalent discharge diameter for fans with axis of rotation perpendicular to the discharge flow and at least 2.0 times the fan equivalent discharge diameter for fans with axis of rotation parallel to the discharge flow.

7. Temperature t_{d7} may be considered equal to t_{d5}.

Figure 12   Outlet Chamber Setup—Multiple Nozzles in Chamber

WET-BULB DEPRESSION °F

Figure 17 Psychrometric Density Chart
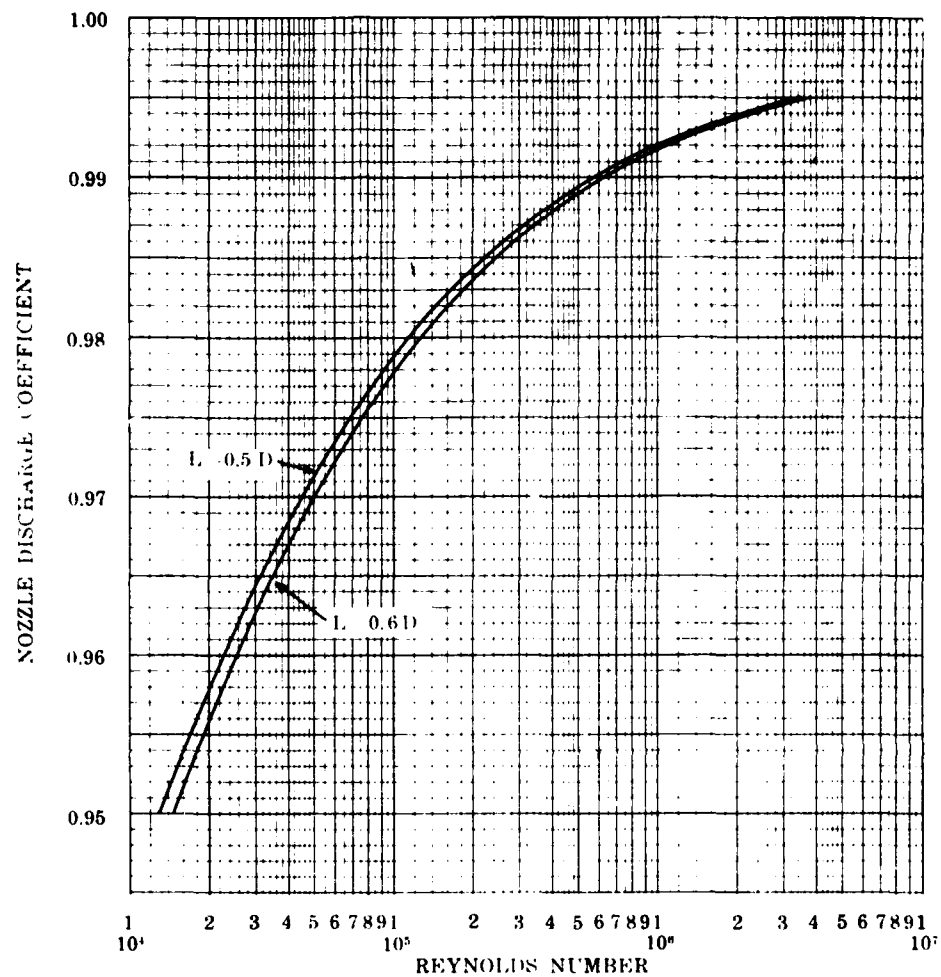
Figure 18 Coefficients of Discharge For Flow Nozzles
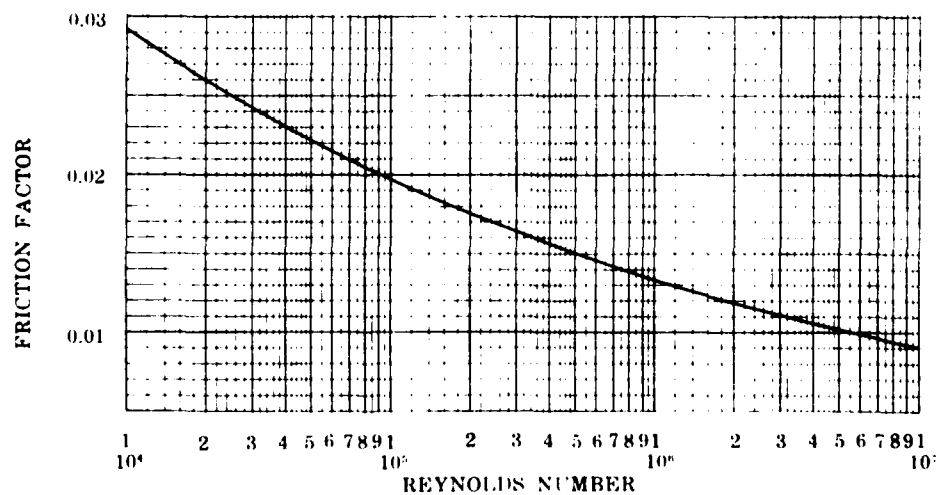
Figure 19 Friction Factors For Ducts
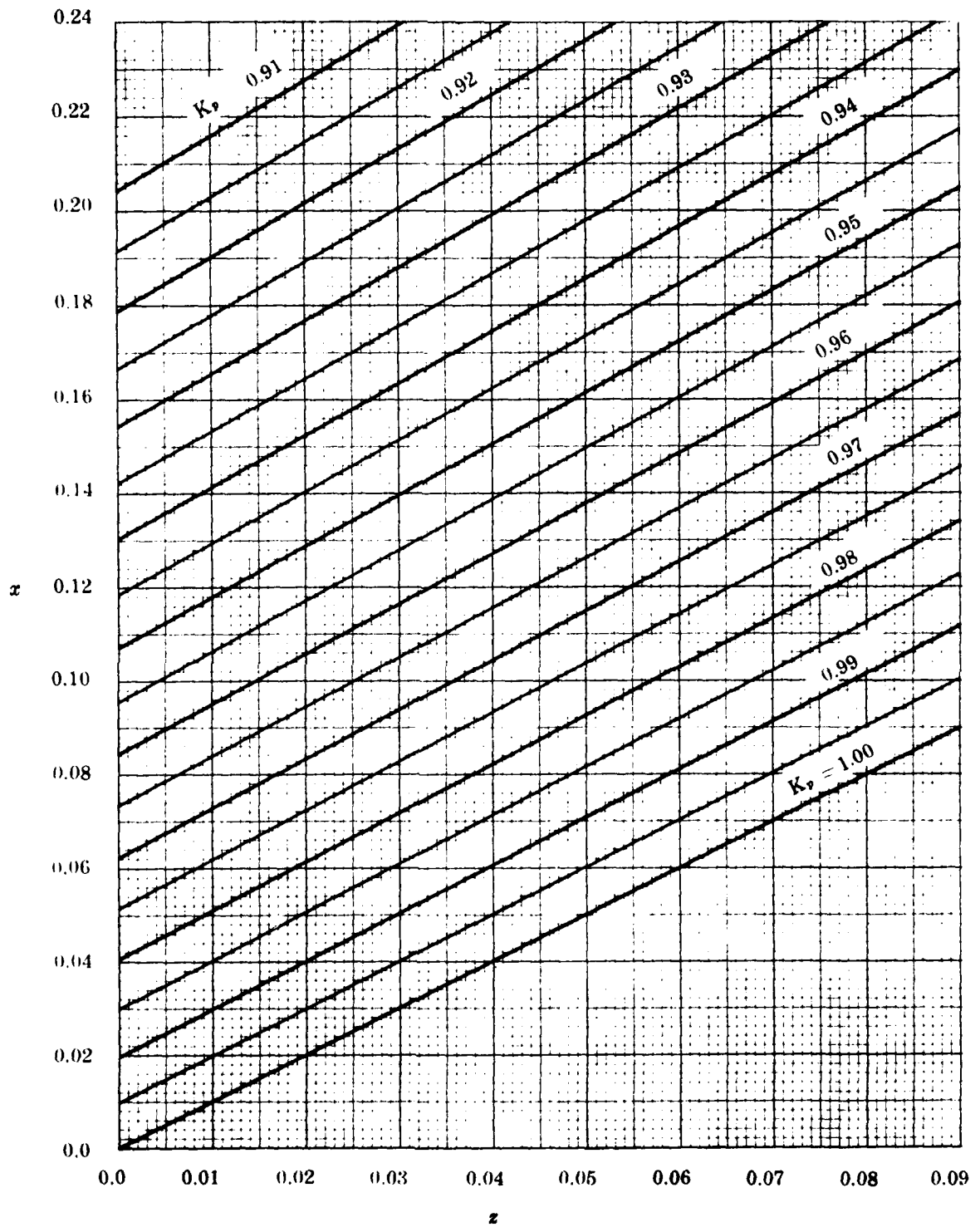
Figure 20 Compressibility Coefficients

IT'S THE LAW

183.605   DEFINITIONS

As used in the subpart --

"ASTM" means American Society for Testing and Materials.

183.607   INCORPORATED BY REFERENCE

(a)(2)   ASTM Standard D-471 dated April 1975.

American Society for Testing and Materials
1916 Race Street
Philadelphia, Pennsylvania 19103

Note 1   *See 183.620(a)(5) for reference to ASTM*

Note 2   *(183.607(b))   The Director of the Federal Register approved the incorporation by reference on September 26, 1976.*

Note 3   *(183.607(a)) - This standard is incorporated in the regulation by reference. Copies may be obtained from the ASTM. It is also available for inspection at*

U.S. Coast Guard Headquarters, Room 4220
2100 Second Street, S.W.
Washington, DC 20593, and

Office of the Federal Register Library, Room 8401
1100 L Street, N.W.
Washington, DC 20408

Note 4   *The pertinent paragraphs of ASTM D 471 are as follows:*

5. Standard Test Liquids

5.1 For purpose of test, it is usually desirable to use the liquid with which the vulcanizate will come in contact in service. For comparative tests with liquids of unknown or doubtful composition, samples of liquid from the same drum or shipment shall be used. Many commercial products, particularly those of petroleum origin, are subject to sufficient variation that it is not practical to use them for test liquids. It is then advisable to use a standard test liquid, such as described in 5.1.1 and 5.1.2, covering the range of properties that may be encountered in the particular service.

5.1.1 *ASTM Oils*—The test shall be conducted in one of the petroleum-base ASTM oils (Note 1) specified in Table 1 which has its aniline point nearest that of the oil with which the vulcanizate is expected to come in contact in service except as indicated in 5.1.3.

NOTE 1—The aniline point of a petroleum oil appears to characterize the swelling action of that oil on synthetic rubber. In general, the lower the aniline point, the more severe the swelling action by the oil The oils specified in Table 1 cover a range of aniline points commonly found in lubricating oils.

5.1.2 *ASTM Reference Fuels*—When gasolines are to be encountered in service, the test shall be conducted in one of the ASTM Reference Fuels (Note 2) specified in Table 2, except as indicated in 5.1.3.

NOTE 2—The ASTM Reference Fuels in Table 2 have been selected to provide the maximum and minimum swelling effects produced by commercial gasolines. Reference Fuel A has a mild action on elastomeric vulcanizates and produces results of the same order as low-swelling gasolines of the highly paraffinic, straight-run type. Reference Fuel B has a more severe swelling action on elastomeric vulcanizates and exceeds the swelling action of commercial gasoline. Reference Fuel C has a more severe swelling action which is typical of these experienced with highly aromatic premium grades of automotive gasolines.

TABLE 2   ASTM Reference Fuels

Reference Fuel A	Isooctane*
Reference Fuel B	Isooctane,* 70 volume percent
	Toluene,* 30 volume percent
Reference Fuel C	Isooctane,* 50 volume percent
	Toluene,* 50 volume percent

* *Isooctane conforming to Section Annex A 2.8, Motor Fuels Section, of the 1973-74 ASTM Manual for Rating Motor, Diesel, and Aviation Fuels*
* *Toluene conforming to ASTM Specification D 362, for Industrial Grade Toluene*

IT'S THE LAW

183.605   DEFINITIONS

As used in this subpart –

"Fuel" means gasoline

Alcohol extended gasoline (gasohol) and other such gasoline based fuels are included in the defined term "fuel".

Diesel Fuel and compressed gaseous fuels (LPG, CNG, etc.) are not included.

IT'S THE LAW

183.605   DEFINITIONS

As used in this subpart –

"Open to the atmosphere" means a compartment that has at least 15 square inches of open area directly exposed to the atmosphere for each cubic foot of net compartment volume.

OPEN AREA LOCATIONS

The location of the opening(s) is (are) not specified. Open areas may be at the bottom, at the side or at the top of a compartment as long as:

– the open area equals 15 square inches for each cubic foot of net compartment volume. (See Figure 2), and
– the opening is directly exposed to the atmosphere.

Notes: 1. *A number of openings may be added together in order to obtain the required total.*

2. *Openings into an open cockpit are acceptable.*

NET COMPARTMENT VOLUME

Net compartment volume is the result of subtracting the volume of installed items of equipment and accessories from the total compartment volume. Examples of items that may be subtracted include:

Engines
Tanks – Fuel, Water, etc.
Auxiliary Generators
Other Auxiliary Equipment
Batteries
Accessory equipment such as refrigeration machinery, pressure fresh water systems, etc.
For outboard boats – one portable 6 gallon fuel tank.

Examples of items that are not subtracted include:

Stowed Fenders
Stowed Anchor and Line
Stowed Chairs
Picnic Coolers
Other items that may or may not be in a compartment at any given time.

To assist in determining the amount of cubic feet to subtract, refer to Table I for suggested volumes of engines and batteries, and Figure 3 for a graph of tank capacity vs tank volume in cubic feet.

FIGURE 2 · OPEN AREA
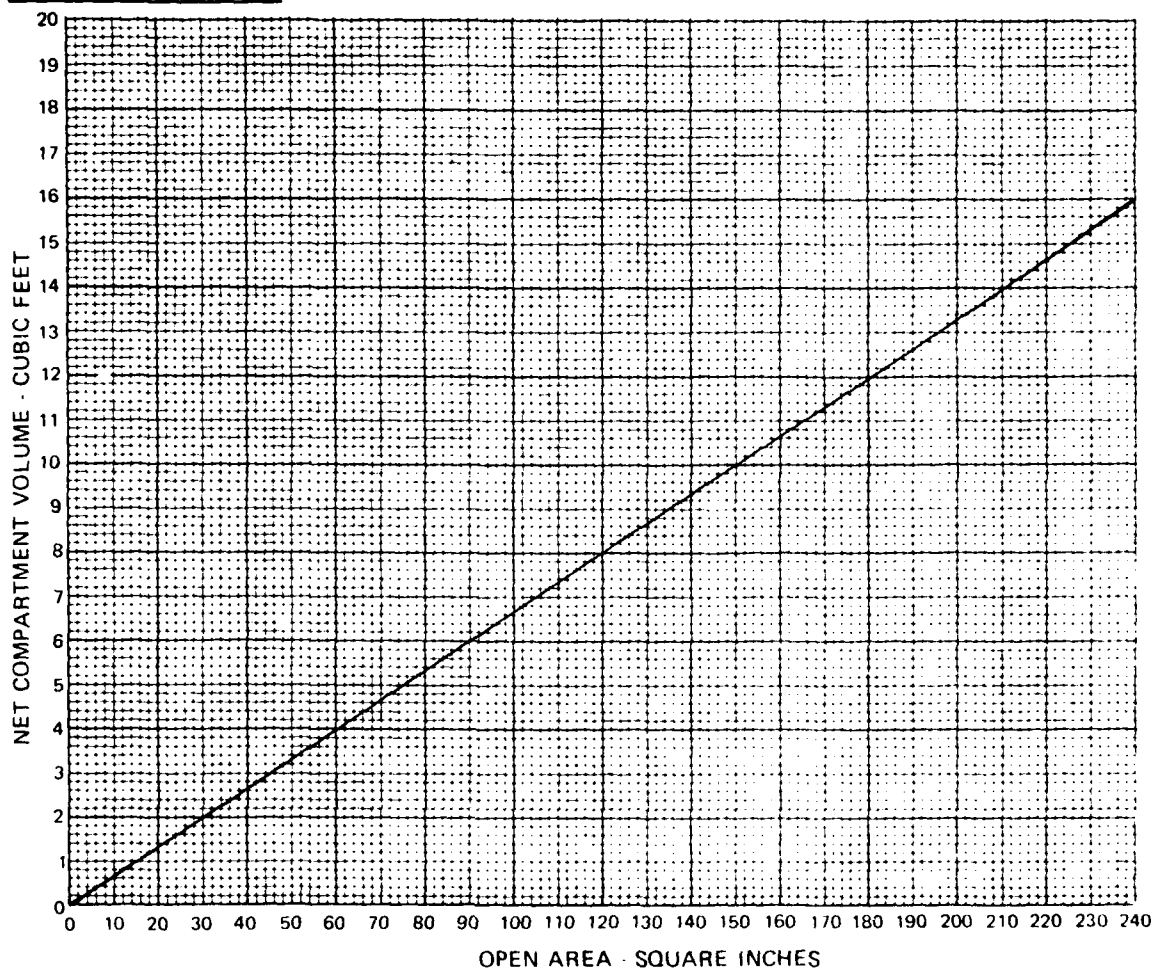
TABLE I — TYPICAL VOLUMES OF ENGINES AND BATTERY

ENGINES

4 cyl. in line		2.5 cu. ft. each
6 cyl. in line		3.5 cu. ft. each
	V6	4.0 cu. ft. each
Small	V8	4.5 cu. ft. each
Large	V8	5.5 cu. ft. each

BATTERY

1/2 cu. ft. each battery

FIGURE 3 - TANK VOLUMES
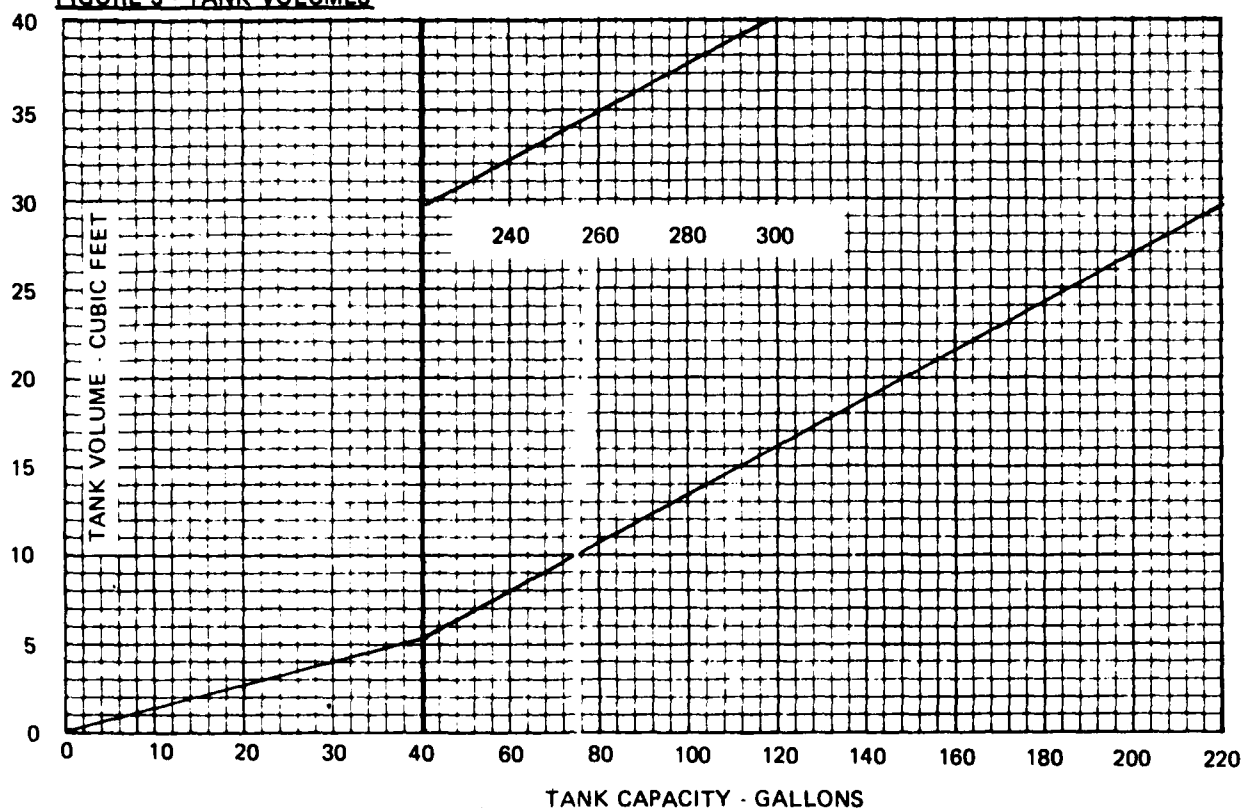
FORMULA:

Tank volume (cu. ft.) = 0.134 x Tank Capacity (gallons)

For outboard boats one 6 gallon portable tank = 0.8 cu. ft.

— — — — — — —

SCREENS AND LOUVERS

If openings into a compartment are screened or louvered the area of opening is the net open area of the screen or louver.

CONNECTING COMPARTMENTS

The regulation is not specific about compartments that adjoin a compartment that is to qualify as "open to the atmosphere". The following discussion presents acceptable ways of handling this problem but they are not necessarily the only ways.

An adjoining compartment that has an opening into a compartment that is to be "open to the atmosphere" may also be "open to the atmosphere" if:

— the total of all open areas directly exposed to the atmosphere from both compartments is at least 15 square inches for each cubic foot of the combined net compartment volumes.

See Figure 4 for diagrams depicting some examples of connecting compartments.

44

40 SQ. IN.   STARBOARD COMPARTMENT - 5 CU. FT. ●—— OPENING BETWEEN COMPARTMENTS

450 SQ. IN. TOTAL OPEN AREA NEEDED TO
QUALIFY COMPARTMENTS AS " OPEN TO
THE ATMOSPHERE".

AFT

COMPARTMENT

20 CU. FT.

370 + 40 + 40 = 450

370 SQ. IN. " OPEN TO THE ATMOSPHERE "

40 SQ. IN.   PORT COMPARTMENT - 5 CU. FT. ●—— OPENING BETWEEN COMPARTMENTS
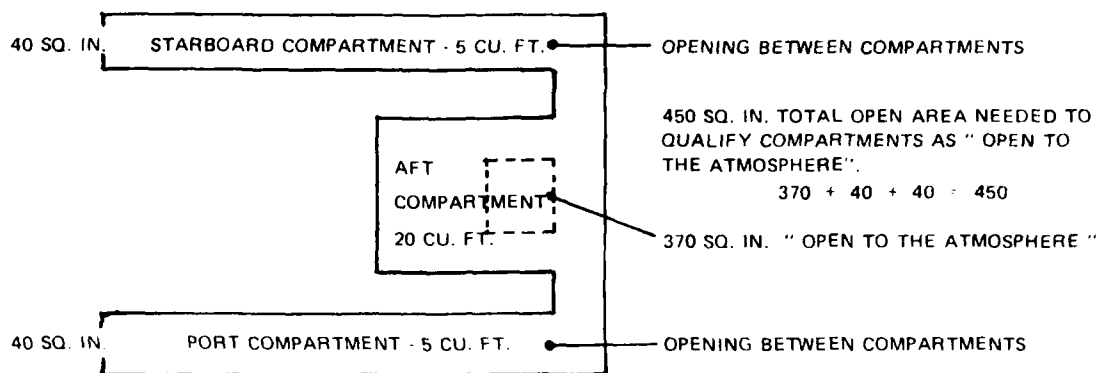
NOTE · *The principle depicted above may be applied to I/O boats with ski racks along the sides , or to boats with bottom compartments between stringers.*

300 SQ. IN.

COMP'T | COMPARTMENT

75 SQ. IN.

NO. 2 | NO. 1

5 CU. FT. | 15 CU. FT.

225 SQ. IN. for COMPARTMENT NO. 1
75 SQ. IN. for COMPARTMENT NO. 2
300 SQ. IN. TOTAL OPEN AREA

BULKHEAD OPENING - 15 SQ. IN. PER CU. FT. OF VOLUME
OF COMPARTMENT NO. 2

50 SQ. IN.   250 SQ. IN.

COMP'T | COMPARTMENT

NO. 2 | 25 SQ. IN. | NO. 1

5 CU. FT. | 15 CU. FT.

225 SQ. IN. OPEN AREA REQUIRED for
COMPARTMENT NO. 1
75 SQ. IN. OPEN AREA REQUIRED for
COMPARTMENT NO. 2
300 SQ. IN. TOTAL OPEN AREA REQUIRED

BULKHEAD OPENING - NET AREA REQUIRED SUCH THAT THE
TOTAL OPEN AREA IS 15 SQ. IN. PER CU.
FT. OF VOLUME OF COMPARTMEN, NO. 2
(In this case 50 + 25 = 75)

REMOVABLE ENCLOSURES

Weather enclosures should not cover ventilation openings. It is reasoned that these enclosures are not airtight and must be opened in order to enter the boat. Upon entering, any gasoline vapors present should be able to be detected by means of their odor. Snap-in bulkheads, such as motor well curtains are not weather enclosures and may require the enclosed compartment to be ventilated. If an open compartment is covered by removable fabric type, weather enclosures they may be ignored.

Note 1.   *See 183.610(b) for reference to UL*

Note 2.   *(183.607(b))   The Director of the Federal Register approved the incorporation by reference on March 24, 1978.*

Note 3.   *(183.607(a))   This standard is incorporated in the regulation by reference. Copies may be obtained from UL.*

It is also available for inspection at

U.S. Coast Guard Headquarters, Room 4220
2100 Second Street, S.W.
Washington, D.C. 20593 and

Office of the Federal Register Library, Room 8401
1100 L Street S.W.
Washington, D.C. 20408

Note 4.   *The pertinent paragraphs of UL 1128 are as follows:*

24. Blower Performance Curve

24.1   A performance curve shall be prepared for all blowers in accordance with paragraphs 24.2–24.5. A blower shall be mounted on the blower airflow calibration chamber described in Figure 24.1 and all mating surfaces shall be sealed. After a run-in period of 3 hours at rated voltage, the following tests shall be conducted.

24.2   During all calibration tests, the blower shall be operated at its nominal voltage, as measured at the input connections to the blower. The input current, in amperes, and the RPM of the blower shall be recorded at each calibration point.

24.3   Immediately preceding the calibration test, the barometric pressure and both wet and dry bulb atmospheric temperature readings at the calibration chamber shall be recorded. Following the test, the air density shall be determined by means of a psychrometric density chart and the air flow readings shall be corrected to a standard density of 0.075 pounds per cubic foot (0.120 kg/m^3).

24.4   The static pressure of the chamber shall be varied by controlling the test chamber discharge opening in steps from 0 to the maximum static pressure developed by the blower (all discharge openings closed). An auxiliary blower connected to the chamber discharge shall be used to obtain the lower static pressure readings. Chamber static pressure shall be measured with an inclined manometer connected to a piezometer ring located at the input end of the chamber. Air flow shall be determined by the pressure differential measured across the calibrated long radius flow nozzles. The pressure differential readings shall be made on an inclined manometer connected to the piezometer rings located on either side of the nozzle plate.

24.5   The following data shall be plotted:

A. Static pressure versus air flow in cubic feet per minute (CFM),

B. Current in amperes versus air flow in CFM, and

C. Blower speed in RPM versus air flow in CFM.

FIGURE 24.1
BLOWER TEST TUNNEL

CONTROLLABLE DISCHARGE ORIFICE

6" (152 mm)

CALIBRATED AIR FLOW NOZZLES

PIEZOMETER RINGS FOR DIFFERENTIAL PRESSURE MANOMETER

AIRTIGHT MOVABLESPLIT IN CHAMBER FOR ACCESS TO NOZZLE PLATE

1-1/2" (37.2 mm)

14" (347 mm)

EGG CRATE AIR STRAIGHTENER

8 FEET (2.44 m)

SCREEN

1-1/2" (37.2 mm) SQUARE OPENINGS

6" (152 mm)

2' 5" (737 mm)

4' (1.22 m)

PIEZOMETER RING

BLOWER MOUNTING PLATE

AIR DIFFUSION SCREEN

19" (483 mm)

2' (610 mm)

5/8" (15.9 mm)

BE 118-1

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POWERED VENTILATION

Requirements

Blowers

    Rated Blower Capacity

    Blower System Output

Duct Placement

Boat Label

IT'S THE LAW

183.610 POWERED VENTILATION SYSTEM

(a) Each compartment in a boat that has a permanently installed gasoline engine with a cranking motor must —

(1) Be open to the atmosphere, or

(2) Be ventilated by an exhaust blower system.

EFFECTIVE DATE: August 1, 1980.
(Compliance on or after August 1, 1978 is acceptable.)

DEFINITION OF TERMS

A "Compartment" is any space in a boat that has length, width and height. It may be completely enclosed, partially enclosed or have one of its surfaces completely open such as a compartment under a bow deck or a compartment under a motor well, if there is no enclosing bulkhead.

"Permanently installed" with regard to an engine, means that it is securely fastened to the boat's structure and the necessary wiring, piping and controls are connected and secured to the boat in accordance with the applicable USCG regulations. (33CFR Part 183, Subpart I Electrical Systems and 33 CFR Part 183, Subpart J, Fuel Systems). The use of "Permanently installed" is to highlight its difference from the use of portable equipment.

The terminology "gasoline engine with a cranking motor" is used to indicate that the gasoline engine can be started from a location that is remote from the compartment in which they are permanently installed. An engine without a cranking motor (starter) would require the presence of a person at the engine location in order to start it. Presumably, any dangerous conditions such as liquid fuel or vapors being present would be detected and remedied before the person would start the engine.

COMPLIANCE

Therefore this section of the regulation speaks to those boats that have an "engine with a cranking motor", "permanently installed" in a "compartment". To comply with the regulation, one of the following two alternatives must be satisfied.

1. The compartment must be "open to the atmosphere" as the terminology is defined in 183.605 "Definitions" and discussed on pages 42 to 45 of this guideline, or

2. There must be an "exhaust blower system" installed to ventilate the compartment in which the engine is installed. An "exhaust blower system" consists of one or more blowers, and usually ducting and terminal fittings attached to the ducts.

DO YOU COMPLY

1. Is there a gasoline engine in the compartment?   (   )
2. Is the gasoline engine permanently installed?   (   )
3. Does the gasoline engine have a cranking motor (starter)?   (   )

If you have answered "NO" to any of the above, see Section 182.620 "Natural Ventilation".

If you have answered "YES" to all of the above then you must answer "YES" to one of the following:

1. Is the compartment "open to the atmosphere" (see pages 42 - 45 for requirement)?   (   )
2. Is there an "exhaust blower system"? (see sections 183.610(b), (c), (d), (e) and (f)   (   )
   for requirements).

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183.610 POWERED VENTILATION SYSTEM

(b) Each exhaust blower or combination of blowers must be rated at an air flow capacity not less than that computed by the formulas given in Table 183.610, Column 2. Blower rating must be determined according to AMCA Standard 210-74, Figure 12, dated 1974, or UL Standard 1128 dated August 23, 1977.

Table 183.610

Column 1[1]	Column 2[2]	Column 3[3]
Below 34	Fr=50	FO=20
34 to 100	Fr=1.5V	FO=0.6V
Over 100	Fr=V/2 + 100	FO=0.2V + 40

[1] Net compartment volume of engine compartment and compartments open thereto   (V) cubic feet.

[2] Rated blower capacity   (Fr) cubic feet per minute.

[3] Blower system output   (FO) cubic feet per minute.

EFFECTIVE DATE: August 1, 1980.
(Compliance on or after August 1, 1978 is acceptable.)

COLUMN 1   NET COMPARTMENT VOLUME

The volume ranges indicated in Column 1 of Table 183.610 are net compartment volumes (V) of the engine compartment.

Net compartment volume is the result of subtracting the volume of permanently installed items, such as engine(s), fuel tanks, equipment and accessories from the total compartment volume of the compartment. A discussion of the items that may and may not be included, and suggestions for accounting for engines and fuel tanks appears as part of the discussion under section 183.605 on pages 42 - 45 of this guideline.

The compartment volume may be obtained by determining the average cross sectional area of the compartment in square feet and multiplying it by the length of the compartment in feet. The answer to this computation will be the compartment volume in cubic feet. For an irregular compartment the volumes of portions of the compartment may be computed separately and combined to get the total compartment volume. To get the net compartment volume subtract the installed items as referred to above.

The net volume of adjoining compartments may have to be added to the engine compartment volume. The following rules apply:

ADD   If the area of openings between compartments is more than 2% of the area of the separation structure (bulkheads, stringers, frames, etc).

DO NOT ADD   If the area of openings between compartments is equal to or less than 2% of the area of the area of the separation structure (bulkheads, stringers, frames, etc.).

The total net volume of the engine compartment including connecting compartments whose volumes are required to be ADDED (Column 1 of Table 183.610) is used to determine the required "rated blower capacity" (Column 2 of Table 183.610) and the "blower system output" (Column 3 of Table 183.610).

FIGURE 5 - RATED BLOWER CAPACITY

NET COMPARTMENT VOLUME - CU. FT.

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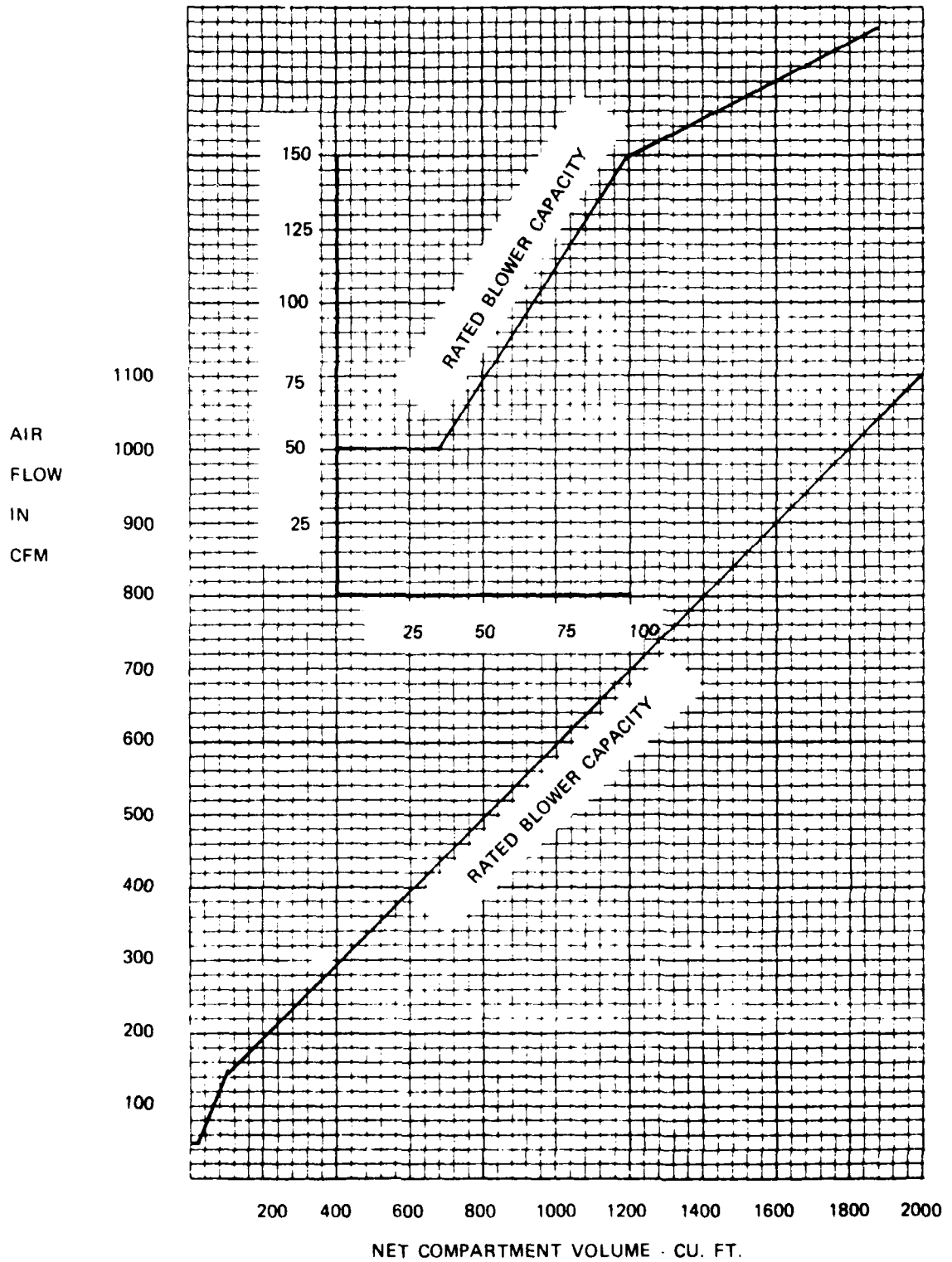
COLUMN 2 — RATED BLOWER CAPACITY

The air flow capacity rating (Fr) of blowers is to be determined by one of two procedures.

1.   *AMCA Standard 210 - 74, Figure 12, - dated 1974, or*

2.   UL Standard 1128 - dated August 23, 1977.

Refer to Definitions section of this guideline for the applicable portions of these two standards. The AMCA Standard is a general standard for testing many types of air moving equipment. The UL Standard is specifically for testing marine blowers.

Since the UL test procedure was derived from the AMCA Standard, the test results should be the same regardless of which standard is used to test a blower.

BLOWER SIZE SELECTION

The total rated capacity of the required blower or blowers (Fr) is based on the net compartment volume (V) as specified in Table 183.610. It is noted that one or more blowers may be used to provide the required capacity. Figure 5 is a graph of "rated blower capacity" versus "net compartment volume".

Example 1   *The net compartment volume of an engine compartment in a boat is 20 cubic feet.*

The rated blower capacity is 50 cubic feet per minute.

Normally one blower will satisfy this compartment.

Example 2   *The net compartment volume of an engine compartment is 100 cubic feet.*

The rated blower capacity is 150 cubic feet per minute.

Two blowers could be used to satisfy this requirement — one rated at 100 cubic feet per minute and one rated at 50 cubic feet per minute. One 150 cubic feet per minute blower would, of course, satisfy the requirement. Blowers with higher capacity ratings than the minimum may be used.

Example 3   *The net compartment volume of an engine compartment is 800 cubic feet.*

The rated blower capacity is 500 cubic feet per minute.

Again one, two or more blowers may be used to satisfy this requirement. Since available marine blowers, two 200 cubic feet per minute and one 100 cubic feet per minute blowers might be selected. Blowers with higher capacity ratings than the minimum may be used.

DO YOU COMPLY

Answer "YES" to one of the following:

Is the blower rated in accordance with AMCA Standard 210 - 74, Figure 12 dated 1974?, or   (   )

Is the blower rated in accordance with UL 1128 Marine Blower Standard dated August 23, 1977? (May be evidenced by the display of the UL Marine Label).   (   )

Having determined the net compartment volume (Column 1)

is the rated blower capacity of the blower or blowers selected at least that required in Column 2?   (   )

IT'S THE LAW

183.610   POWERED VENTILATION SYSTEM

    (c)   Each exhaust blower system required by paragraph (a)(2) of this section must exhaust air from the boat at a rate which meets the requirements of Table 183.610, Column 3 when the engine is not operating.

Table 183.610

Column 1[1]	Column 2[2]	Column 3[3]
Below 34	Fr 50	FO=20
34 to 100	Fr -1.5V	FO=0.6V
Over 100	Fr V/2 + 100	FO=0.2V + 40

[1] *Net Compartment volume of engine compartment and compartments open thereto — (V) cubic feet.*

[2] *Rated blower capacity (Fr) cubic feet per minute.*

[3] *Blower system output (FO) cubic feet per minute.*

EFFECTIVE DATE: August 1, 1980.
(Compliance on or after August 1, 1978 is acceptable)

COLUMN 1 and COLUMN 2 were discussed under 183.610(b) on the previous pages.

COLUMN 3   BLOWER SYSTEM OUTPUT

A "blower system" includes the items and devices used to convey ventilation air flow into and out of a boat. Examples of such items and devices, but not to exclude others, are as follows:

        Blower(s)
        Ducting
        Terminal fittings
        Cowls, scoops, funnels
        Screens
        Dorade boxes

The air flow required (FO) for the exhaust blower system is like the rated blower capacity in that it is based on the _net_ compartment volume (V) (COLUMN 1). The "blower system output" is stated in COLUMN 3 of Table 183.610. These "blower system output" requirements establish the minimum efficiency permitted (40%) for an exhaust blower system design. Each item or device used in a blower system offers resistance to the air flow available at the blower. To be considered in the design of a blower system are the following:

        Duct resistance
        Duct bend resistance (the tighter the bend the higher the resistance).
        Terminal fittings (end brackets, Y fittings, adapters, etc.).
        The distance that duct opening is away from a surface that could obstruct air flow.
        Cowl, scoop or funnel resistance.
        Screen resistance.
        Dorade box resistance.

The above list is not intended to exclude any item or device in the blower system that might offer resistance to air flow.

If more than one blower is used, the "blower system output" is the total quantity of air from all blowers in cubic feet per minute exhausted from the boat. Figure 6 is a graph of "blower system output" versus _net_ compartment volume.

FIGURE 6 - BLOWER SYSTEM OUTPUT

FIGURE 6 - BLOWER SYSTEM OUTPUT
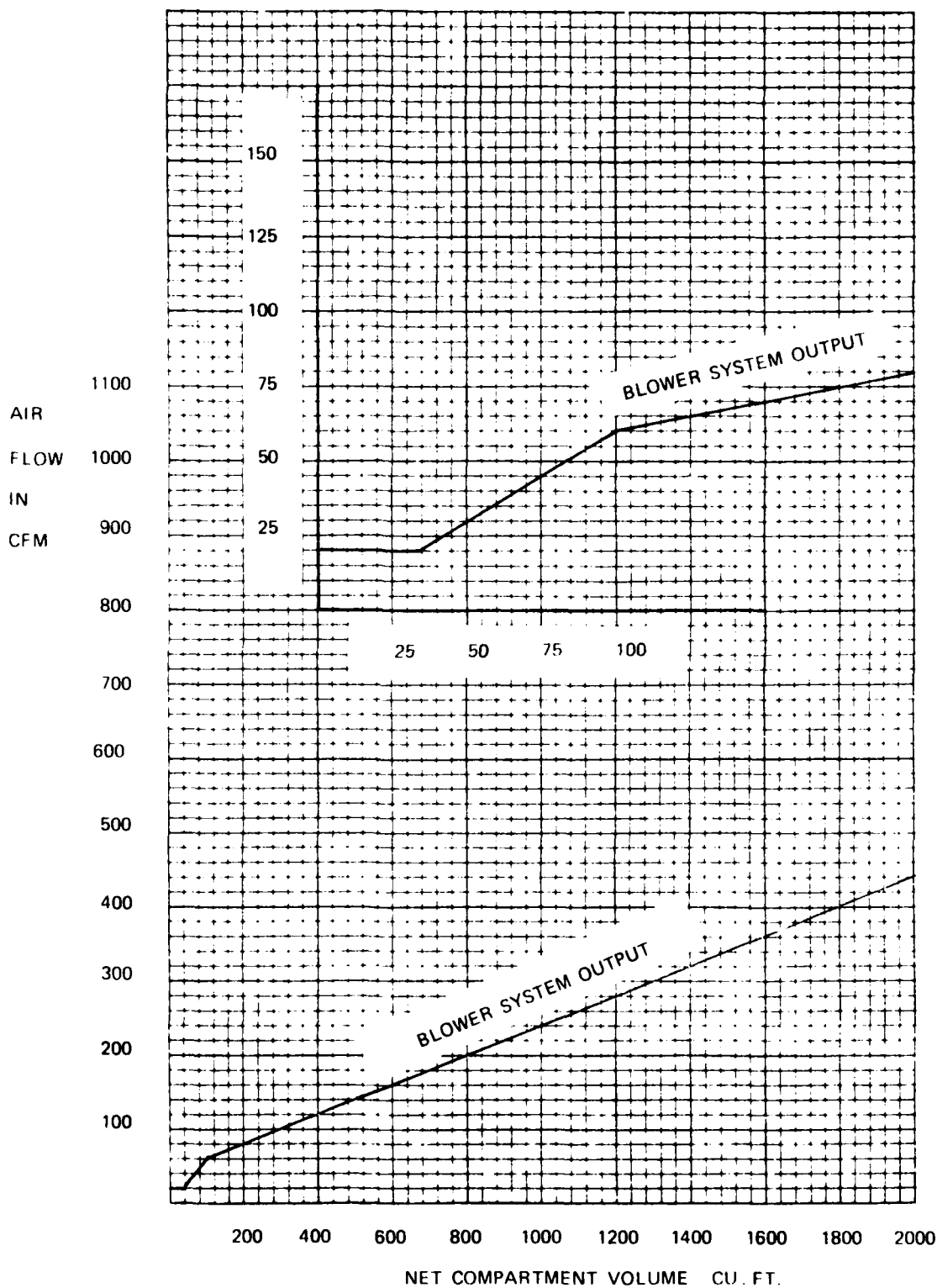
FIGURE 7 · TYPICAL BLOWER PERFORMANCE CURVES

AIR FLOW (CFM) vs STATIC PRESSURE (INCHES OF WATER)

MANUFACTURER:
VOLTAGE; 12 Volts D.C.   MODEL:
AIR DENSITY LBS/FT^3 0.0736   MOTOR:
CORRECTED TO: .075
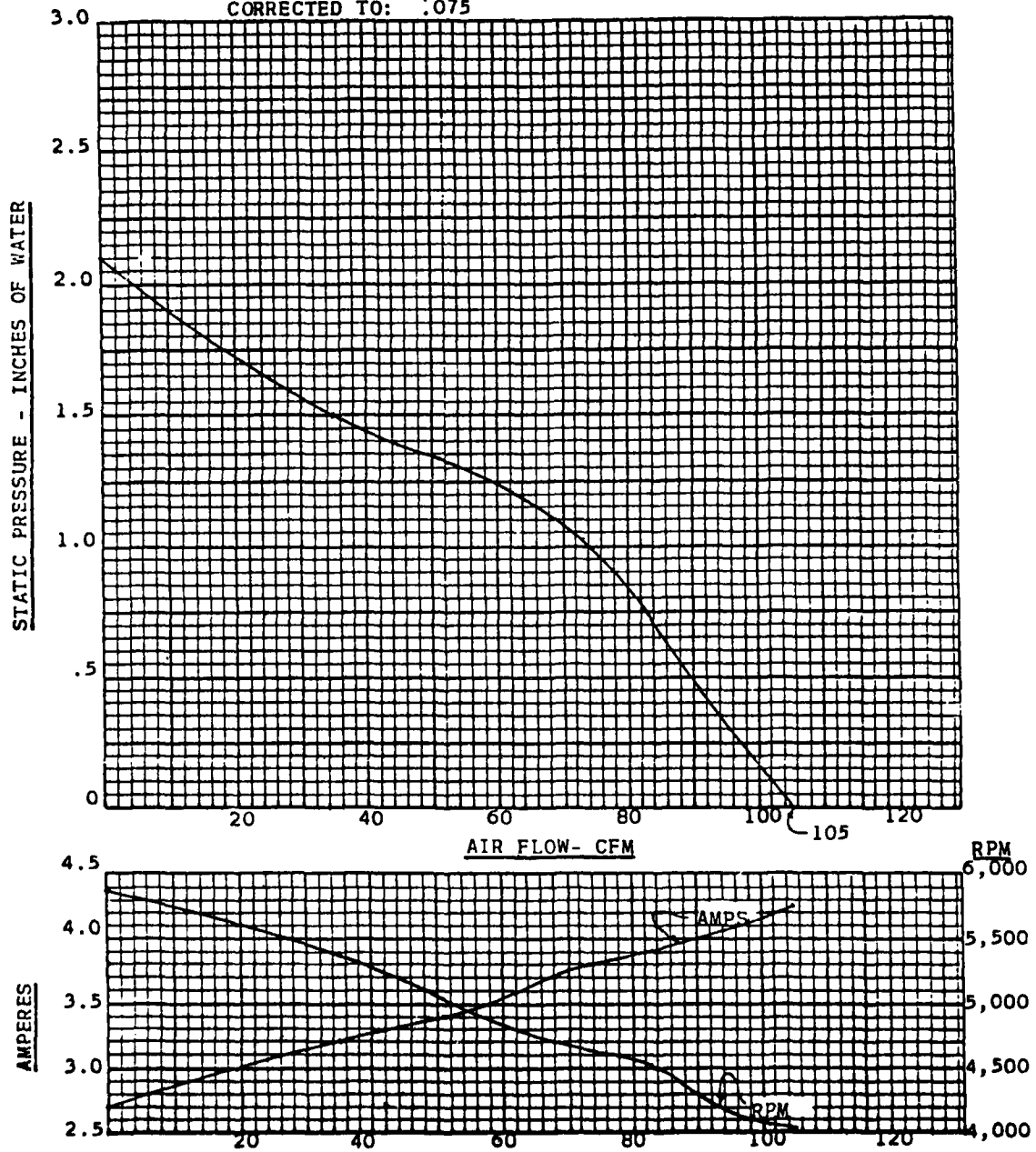
EXHAUST BLOWER SYSTEM AIR FLOW DETERMINATION

During the process of rating a blower, curves of blower performance are usually developed and are required if tested in accordance with the UL 1128 "Marine Blower's" standard. The curves show air flow for various static pressures and also record the current and RPM of the blower at these airflows. See Figure 7 for a typical set of blower curves.

VENTILATION SYSTEM DESIGN

In laying out a powered ventilation system it would be helpful to have some idea of what the system output might be before the boat is built. The "rules of thumb" presented here are based on data accumulated from a number of isolated tests and are not to be used to determine compliance with the regulation. They may only be used to estimate the "blower system output".

TABLE II   ESTIMATED EFFECT OF BLOWER SYSTEM COMPONENTS

Item	Percent Loss of Blower Rated Capacity
Ducting	2% per ft. of length
Ducting bends 90°	10% each bend
Clamshell	20%
Louver	20%
Screen 1/4" mesh	10%

NOTE: Lower resistance items may be selected resulting in an improved system efficiency.

Example.   A contemplated blower system has a 5 foot duct (10%), one 90° bend (10%), a clamshell (20%) and a screen (10%).

Therefore the estimated "blower system output" is 50% less than the "blower rated capacity".

FIGURE 8   METHOD 1   Current Measurement

VOLTMETER
NOMINAL VOLTAGE

AMMETER

RHEOSTAT
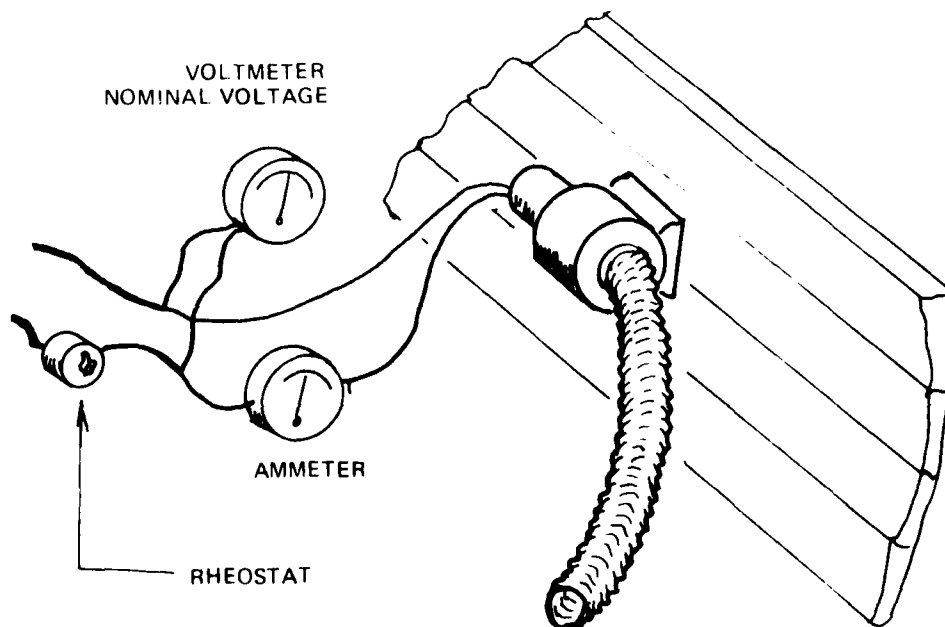
To obtain the air flow of an exhaust blower system using the blower performance curves then becomes an easy task. The following outlines two methods that may be used on an installed system:

METHOD 1 – Current Measurement (See Figure 8)

Step 1. Connect an ammeter into the wiring going to the blower.

Step 2. Energize the blower at its nominal voltage; e.g. 12, 24, 32 volts etc. A rheostat may be needed to control the voltage.

Step 3. Read the current draw in amperes. The boat's engine is not to be operating when taking this reading.

Step 4. Enter the performance curves at the determined amperage and read the air flow in cubic feet per minute (CFM).

METHOD 2 – RPM Measurement (See Figure 9)

Step 1. Energize the blower at its nominal voltage; e.g. 12, 24, 32 volts etc. A rheostat may be needed to control the voltage.

Step 2. Determine the RPM of the blower. A stroboscope is one instrument that may be used to read RPM of rotative machinery. The boat's engine is not to be operating during this reading.

Step 3. Enter the performance curves at the determined RPM and read the air flow in cubic feet per minute (CFM).

FIGURE 9 - METHOD 2 — RPM Measurement

STROBOSCOPE

READ RPM
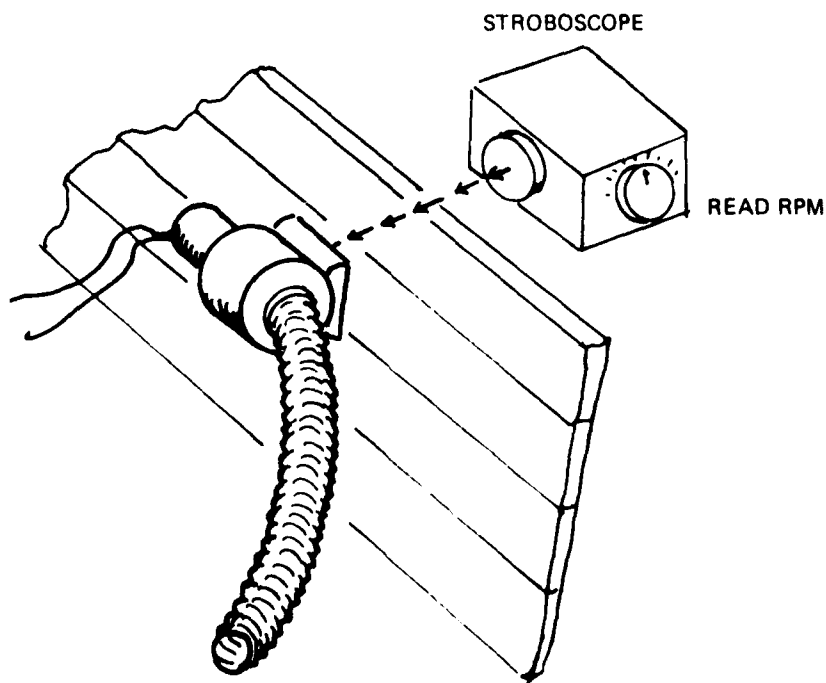
Both of the above methods are accurate means for determining the effective air flow of an exhaust blower system. Also there are numerous instruments that measure air velocity in feet per minute.

METHOD 3   AIR VELOCITY MEASUREMENT

To obtain air flow in cubic feet per minute requires:

- determination of the cross sectional area of the duct, at the measuring point, in square feet.
- determination of the average air velocity across the duct at the measuring point. The air velocity varies from the duct surface to the center of the duct. (See Figure 10).
- multiplying the cross sectional area in square feet by the average air velocity in feet per minute will provide the air flow in cubic feet per minute. (CFM).

This method may not be accurate as it depends on the ability to determine an accurate average air velocity. It may be possible to develop a correlation between this method and one of the Methods 1 or 2 in which case this method may prove satisfactory. Also if duct air flow theory and the associated formulas are familiar they could be used.

FIGURE 10   METHOD 3   Air Velocity Measurement

AIR VELOCITY METER

READ AIR VELOCITY   FEET PER MINUTE

AIR VELOCITY VARIES DUE TO DUCT FRICTION
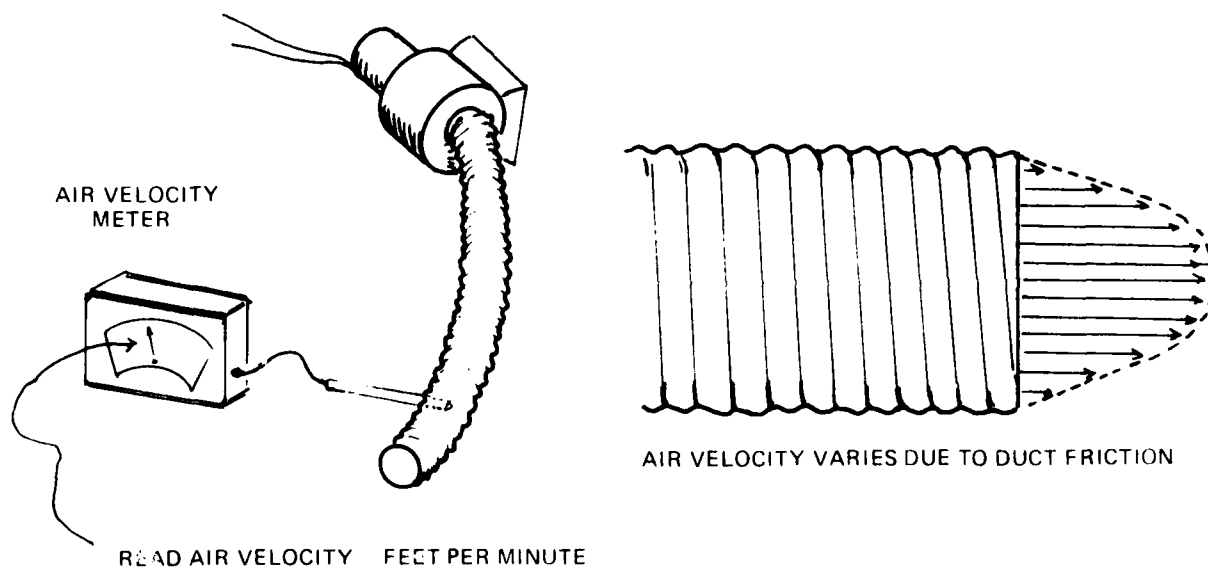
DO YOU COMPLY

Having determined the net compartment volume (Column 1);

Is the exhaust blower system output at least that required in Column 3 when the engine is not operating.   (   )

IT'S THE LAW

183.610   POWERED VENTILATION SYSTEM

(d)   Each intake duct for an exhaust blower must be in the lower one-third of the compartment and above the normal level of accumulated bilge water.

EFFECTIVE DATE: August 1, 1980
(Compliance on or after August 1, 1978 is acceptable).

The duct connected to the intake side of the blower is used to select the point in a compartment where the compartment air will be exhausted. The purpose of exhausting air is to remove potentially explosive or flammable vapors that may have accumulated in the compartment during normal operation of the boat. It is intended that the ventilation required by this regulation be sufficient to maintain safe operating conditions under normal circumstances. What this means is, that ventilation can not be relied upon to remove liquid fuel or all its vapors such as might be present if there is a leak in the fuel system.

The vapors that may occur during normal operation are usually those associated with carburetor boil-off after the engine is turned off. These vapors will usually flow to and collect in the lowest part of the compartment. The regulation requires that the exhaust blower duct opening be located so that it is "in the lower one-third of the compartment". This is to get the intake opening into the portion of the compartment where the vapors are most likely to collect. Usual locations include:

- under an engine
- between engine stringers
- at a sump, possibly provided as a bilge water collecting point.

In addition, consideration must be given to the possibility of normal bilge water accumulations covering the intake opening. "Normal accumulations of bilge water" is that which occurs from propeller shaft stuffing box seepage, spray while operating the boat, and rain. The water remaining in the boat after a bilge pump completes its normal pumping cycle would be considered normal. The opening of the exhaust blower intake duct must be above this "normal level of accumulated bilge water".

It is important to evaluate each engine compartment design and to locate the intake opening of the exhaust blower duct so it will be in the best position to remove any collected vapors.

DO YOU COMPLY

Is the intake opening of the exhaust blower duct –

Located in the lower one-third of the compartments?   (   )

Above the normal level of accumulated bilge water?   (   )

IT'S THE LAW

183.610   POWERED VENTILATION SYSTEM

(e)   More than one exhaust blower may be used in combination to meet the requirements of this section.

EFFECTIVE DATE: August 1, 1980
(Compliance on or after August 1, 1978 is acceptable)

This section authorizes the use of more than one blower in a compartment in order to provide the required "rated blower capacity" and the required "blower system output". The use of one or more blowers has been discussed under the previous sections.

Since this section is a statement of permitted use of more than one blower, there is no specific compliance question.

183.610   POWERED VENTILATION SYSTEM

(f)   Each boat that is required to have an exhaust blower must have a label that –

(1)   Is located as close as practicable to each ignition switch;

(2)   Is in plain view of the operator; and

(3)   Has at least the following information:

WARNING

GASOLINE VAPORS CAN EXPLODE

BEFORE STARTING ENGINE OPERATE BLOWER FOR 4 MINUTES

CHECK ENGINE COMPARTMENT BILGE FOR GASOLINE VAPORS

EFFECTIVE DATE: August 1, 1980
(Compliance on or after August 1, 1978 is acceptable).

If a blower is required on a boat, there must be a label affixed to the boat. The label must be located such that two requirements are satisfied:

1.   It must be near the ignition switch(es); and
2.   It must be able to be seen by an operator who is in a normal position to operate the ignition switch(es).

Examples of Label Locations

1.   If the ignition switch(es) is (are) on the side of a console then the label(s) should probably be on the top visible surface of the console above the switch(es).

2.   If two ignition switches are located next to each other, then one label could serve both switches.

3.   If two or more ignition switches are provided for one engine such as might be the case with a boat with two steering stations then a label must be at each location. A boat with a flying bridge often has two steering stations.

4.   If a boat is equipped with auxiliary gasoline powered equipment such as a generator, then the ignition switch location for said equipment must have a label.

The label must contain the information specified. It doesn't have to be stated in the exact words used but must deliver the same message.

An acceptable label consists of four elements.

1. The signal word	WARNING
2. The hazard	GASOLINE VAPORS
3. Consequences of the hazard	CAN EXPLODE
4. Action required	BEFORE STARTING ENGINE OPERATE BLOWER FOR 4 MINUTES
	AND
	CHECK ENGINE COMPARTMENT BILGE FOR GASOLINE VAPORS

Additional information may be included on the label. A prepared label has the following format:

> WARNING
>
> Gasoline vapors can explode
> Before starting engine:
> – Check engine compartment for gasoline or vapors.
> – Operate blower for 4 minutes.
> Run blower below cruising speed.

DO YOU COMPLY

Is a blower required?   (   )

If yes, then:

Is there a label installed?   (   )

If yes, then:

    Is there a label near each ignition switch; and   (   )
    Is the label located so that the boat operator can read it   (   )

    Does the label contain at least the information required by 183.610(f)(3)   (   )

NATURAL VENTILATION

When Required

      Compartment Opening

      Ignition Protection

      Fuel Tank Permeability

Performance

      Opening Location

      Air Flow Criteria

      Compartment Exception

Opening Area

      Adjoining Compartments

      Duct and Opening Area

      Terminal Fitting Opening Area

IT'S THE LAW

183.620   NATURAL VENTILATION SYSTEM

(a)   Except for compartments open to the atmosphere, a natural ventilation system that meets the requirements of 183.630 must be provided for each compartment in a boat that —

(1)   Contains a permanently installed gasoline engine:

EFFECTIVE DATE: August 1, 1980
(Compliance on or after August 1, 1978 is acceptable)

NATURAL VENTILATION

Natural ventilation is a term applied to the provisions of air flow inside a compartment that is induced by non-powered means; e.g. ducts, louvers, clamshells, etc. The requirements for the "Natural Ventilation System" are described in detail in the sections of 183.630.

Any compartment that has a permanently installed gasoline fueled engine must have natural ventilation. Engines for propulsion and auxiliary equipment are included.

EXCEPTION: Compartments qualified as "open to the atmosphere", do not require additional ventilation See 183.605 for the definition of "open to the atmosphere".

"Permanently installed" with regard to an engine, means that it is securely fastened to the boat's structure and the necessary wiring, piping and controls are connected and secured to the boat in accordance with the applicable USCG regulations. (33CFR Part 183, Subpart I Electrical Systems, and 33CFR Part 183, Subpart J Fuel Systems). The use of "Permanently installed" is to highlight its difference from the use of portable equipment

DO YOU COMPLY

Is there a gasoline fueled engine permanently installed in the compartment?   (   )

If "YES" then one of the following must be answered "YES".

— Is the compartment "open to the atmosphere" as defined under 183.605? or   (   )

— Is there a "natural ventilation system" provided? (See 183.630 for requirements).   (   )

IT'S THE LAW

183.620   NATURAL VENTILATION SYSTEM

(a)   Except for compartments open to the atmosphere, a natural ventilation system that meets the requirements of 183.630 must be provided for each compartment in a boat that —

(2)   Has openings between it and a compartment that requires ventilation, where the aggregate area of those openings exceeds 2 percent of the area between the compartments, except as provided in paragraph (c) of this section;

(c)   An accommodation compartment above a compartment requiring ventilation that is separated from the compartment requiring ventilation by a deck or other structure is excepted from paragraph (a)(2) of this section.

EFFECTIVE DATE: August 1, 1980
(Compliance on or after August 1, 1978 is acceptable).

OPEN TO THE ATMOSPHERE

Compartments that are "open to the atmosphere" do not require additional ventilation.

ADJOINING COMPARTMENTS

This section along with 183.620(c), which is included above, answers the question;

Is ventilation required for a compartment that has openings into a compartment, such as an engine com-partment, that requires ventilation?

2% RULE

The total area of all openings in the separating structure (bulkheads, stringers, frames, etc.) between the considered compartment and one requiring ventilation, determine whether ventilation is required.

(1) If the total area is more than 2% of the area of the separating structure — natural ventilation is required in the adjoining compartment.

(2) If the total area is equal to or less than 2% of the area of the separating structure — ventilation is not required in the adjoining compartment.

EXCEPTION: Compartments used for accommodations do not require ventilation if:

- *the accommodation compartment is above the compartment requiring ventilation, and*

- *the accommodation compartment is separated from the compartment requiring ventilation by a deck or other structure.*

It is noted that there is no size criteria for the separating structure between an accommodation compartment and a compartment requiring ventilation.

"Accommodation compartments" are those designed for storage or living purposes for persons aboard the boat. Examples of specific uses of accommodation compartments include; staterooms, heads (bath-rooms), galley, pilot house, navigation, workshop and other similar people oriented uses. These uses contrast with engine and fuel tank compartments.

── DO YOU COMPLY ──────────────────────

Is the adjoining compartment requiring ventilation separated by a bulkhead or other structure whose total area of openings is more than 2% of the area of said bulkhead or other structure?   (   )

If "YES", "natural ventilation" is required for said adjoining compartment except as indicated below.

Is the adjoining compartment to a compartment requiring ventilation "open to the atmosphere"?   (   )

If "YES", no additional ventilation is required.

Is the adjoining compartment:

- an accommodation compartment,   (   )

- above the compartment requiring ventilation, and   (   )

- separated by a deck or other structure   (   )

If "YES", to all items then "natural ventilation" is not required.

Is the adjoining compartment to a compartment requiring ventilation, separated by a bulkhead or other structure whose total area of openings is equal to or less than 2% of the area of said bulkhead or other structure.   (   )

If "YES", "natural ventilation" is not required.

183.620   NATURAL VENTILATION SYSTEM

    (a)   **Except for compartments open to the atmosphere, a natural ventilation system that meets the requirements of 183.630 must be provided for each compartment in a boat that**

        (3)   **Contains a permanently installed fuel tank and an electrical component that is not ignition protected in accordance with 183.410(a).**

EFFECTIVE DATE: August 1, 1980
(Compliance on or after August 1, 1978 is acceptable).

OPEN TO THE ATMOSPHERE

    Compartments that are "open to the atmosphere" do not require additional ventilation.

FUEL TANK COMPARTMENTS

    A compartment containing a fuel tank that is "permanently installed", as opposed to a portable tank or container, does not require natural ventilation unless the compartment also contains an electrical component that is not ignition protected.

    Ignition protection is defined in 33 CFR Subpart I   "Electrical Systems", 183.410(a) as follows.

"183.410   IGNITION PROTECTION

    (a)   Each electrical component must not ignite a propane gas and air mixture that is 4.25 to 5.25 percent propane gas by volume surrounding the electrical component when it is operated at each of its manufacturer rated voltages and current loadings, unless it is isolated from gasoline fuel sources, such as engines and, valves, connections, or other fittings in vent lines, fill lines, distribution lines or on fuel tanks, in accordance with paragraph (b) of this section."

Usually fuel level senders and the associated wiring are not sources of ignition and therefore would not normally cause a need for natural ventilation.

Does the compartment contain both:

    a permanently installed fuel tank, and   (   )

    an electrical component that is not ignition protected   (   )

If "YES" then one of the following must be answered "YES".

    Is the compartment, "open to the atmosphere" as defined under 183.605?, or   (   )

    Is there a "natural ventilation system" provided? (See 183.630 for requirement.)   (   )

EFFECTIVE DATE: August 1, 1980
(Compliance on or after August 1, 1978 is acceptable).

OPEN TO THE ATMOSPHERE

Compartments that are "open to the atmosphere" do not require additional ventilation.

FUEL TANK COMPARTMENT - PERMANENTLY INSTALLED FUEL TANKS

A permanently installed fuel tank must have a vent system in accordance with 33 CFR Subpart J "Fuel Systems", 183.520. This section on fuel tank vents requires that vents have a flame arrester and "not allow a fuel overflow at the rate of up to two gallons per minute to enter the boat." In effect this requires a fuel tank vent whose opening is outside of the boat and therefore will not vent into the compartment. For permanently installed fuel tanks 183.620(a)(3) and (5) are more likely to apply.

FUEL TANK COMPARTMENT - PORTABLE FUEL TANKS

Compartments used to store vented portable fuel tanks or containers are required to be equipped with "natural ventilation".

Cockpit seat lockers in auxiliary sailboats are often used as fuel tank compartments for portable outboard motor fuel tanks. If this fuel tank vents into the locker then "natural ventilation" of said locker is required.

Since fuel vapors seek the lowest point of any compartment, this property of gasoline vapors should be considered when designing and constructing a compartment that will contain a fuel tank or container that can vent into said compartment. Any openings in or near the bottom of the compartment could permit explosive vapors to flow into the bilge of the boat where an ignition source might ignite them.

DO YOU COMPLY

Is there a fuel tank in the compartment that vents into said compartment?   (   )

If "YES" then one of the following must be answered "YES".

  Is the compartment "open to the atmosphere" as defined under 183.605?, or   (   )

  Is there a "natural ventilation system" provided? (See 183.630 for requirements.)   (   )

183.620   NATURAL VENTILATION SYSTEM

(a)   Except for compartments open to the atmosphere, a natural ventilation system that meets the requirements of 183.630 must be provided for each compartment in a boat that –

   (5)   Contains a non metallic fuel tank –

      (i)   with an aggregate permeability rate exceeding 1.2 grams of fuel loss in 24 hours per cubic foot of net compartment volume, or

      (ii)   if the net compartment volume is less than one cubic foot, having a permeability rate exceeding 1.2 grams of fuel loss in 24 hours.

   Reference fuel "C" at 40 degrees Celsius plus or minus 2 degrees Celsius from ASTM standard D471 1979, is to be used in determining the permeability rate.

EFFECTIVE DATE: August 1, 1980
(Compliance on or after August 1, 1978 is acceptable.)

OPEN TO THE ATMOSPHERE

Compartments that are "open to the atmosphere" do not require additional ventilation.

PERMEABILITY

Most all plastics and fiberglass will permit gasoline and its vapors to pass through it. This capability of the material is termed "permeability". The "permeability rate" is the quantity of gasoline that passes through the material in a specific length of time or per unit of "net compartment volume". (See 183.605 "Open to the atmosphere" and its discussion for how to determine "net compartment volume".) The "permeability rate" of a material is affected by the thickness and density of the material and the temperature at which the test is conducted may have an effect on the "permeability rate". Therefore, conditions of the test must be controlled as well as standard procedures used.

THE TEST

There are two ways that tests may be conducted to obtain the permeability rate of non metallic materials used for fuel tanks. The two ways are differentiated by how the test sample is prepared.

1.   A test sample of an actual fuel tank may be subjected to the test procedures, or

2.   A test sample of a piece of the fuel tank material may be mounted on a standardized container (such as a 6" x 6" sample) and then submitted to the test procedures with the results extrapolated mathematically to obtain the performance of a full sized tank.

Both of these methods have been used experimentally and appear to correlate.

The fuel to be used in the test, to represent gasoline, has been standardized as ASTM D 471-79 Reference fuel "C". This portion of the ASTM standard appears in 183.605 of this guideline as part of the discussion of the definition of "ASTM".

The U.S. Coast Guard test procedures for "permeability of non metallic fuel tanks" is a separate publication which will become available from:

   National Technical Information Service
   Springfield,
   Virginia 22161

REQUIREMENTS FOR VENTILATION

Permeable non-metallic materials may be used for fuel tanks in boats, however, depending on the permeability rate of the material and the net volume of the fuel tank compartment, "natural ventilation" may be required for the fuel tank compartment.

The regulation evaluates the need for "natural ventilation" of the fuel tank compartment based on whether its net volume is

less than one cubic foot, or

one or more cubic feet.

LESS THAN ONE CUBIC FOOT

A fuel tank compartment whose net volume is less than one cubic foot is required to have "natural ventilation" if the fuel tank's permeability rate is more than 1.2 grams total fuel loss in 24 hours.

ONE OR MORE CUBIC FEET

A fuel tank compartment whose net volume is one or more cubic feet is required to have "natural ventilation" if the fuel tank's permeability rate is more than 1.2 grams of fuel loss per each cubic foot of net compartment volume is a period of 24 hours.

Procedure:

1. Obtain the permeability rate of the non-metallic fuel tank for a 24 hour period in terms of grams of fuel loss.

2. Determine the "net compartment volume" for the fuel tank compartment.

3. Calculate the grams of fuel loss per cubic foot of "net compartment volume".

Example   Total fuel loss for a non-metallic tank is found to be 10 grams in 24 hours.

The net compartment volume for this example is 12 cu ft.

The permeability rate is $\frac{10}{12}$ or .833 grams of fuel loss in 24 hours per cubic foot of net compartment volume.

Conclusion   The fuel tank compartment in the example does not need "natural ventilation" to meet the requirements of the regulation.

Question   What is the minimum net compartment volume before "natural ventilation" is required in the above example?

Answer   Per the example.

the fuel tank loss was stated to be 10 grams in 24 hours.

the permitted fuel loss may not exceed 1.2 grams per cubic foot in 24 hours.

Therefore the net compartment volume must be at least 8.33 cubic feet in order that no ventilation be required. A compartment of less than 8.33 cubic feet of net compartment volume requires "natural ventilation" to be provided.

It is interesting to note that many of the non-metallic materials in current use for gasoline fuel tanks have a permeability rate such that "natural ventilation" of the fuel tank compartment will be required in order to comply with this section of the regulation

DO YOU COMPLY

Is the fuel tank non–metallic? ( )

If "YES", then:

What is the total fuel loss of the fuel tank as determined by a PERMEABILITY TEST conducted for a period of 24 hours using Reference fuel "C" at 40 ± 2°C as described in ASTM D–471–79? (__grams)

1. Is the fuel tank compartment's net volume less than one cubic foot? ( )

   If "NO" see "2".

   If "YES", then:

   a. Is the permeability Rate of the Tank

      1.2 grams or less in 24 hours? ( )

      If "NO" see "b"

      If "YES" NO VENTILATION REQUIRED

   b. Is the Permeability Rate of the Tank

      more than 1.2 grams in 24 hours? ( )

      If "NO" see "a".

      If "YES" NATURAL VENTILATION REQUIRED

2. Is the fuel tank compartment's net volume one or more cubic feet? ( )

   If "NO" see "1".

   If "YES", then:

      What is the Permeability Rate of the Tank, per cubic foot of net compartment volume, in 24 hours? (__grams)

   a. Is it 1.2 grams per cubic foot or less? ( )

      If "NO" see "b".

      If "YES" NO VENTILATION REQUIRED

   b. Is it more than 1.2 grams per cubic foot? ( )

      If "NO" see "a".

      If "YES" NATURAL VENTILATION REQUIRED

183.620   NATURAL VENTILATION SYSTEM

(b)   Each natural ventilation system must be constructed so that –

(1)   Each supply opening required in 183.630 is forward facing and located on the exterior surface of a boat; or

(2)   Air will flow into or out of the supply or exhaust openings required in 183.630 when the boat is in a wind flowing from bow to stern at a velocity of 10 miles per hour when the engine is not operating.

EFFECTIVE DATE: August 1, 1980
(Compliance on or after August 1, 1978 is acceptable).

IS A TEST NECESSARY?

The regulation provides two ways to comply with requirements for placement of openings to be used for a "natural ventilation system". Either means of compliance may be used.

1.   Install supply openings that face forward toward the bow of the boat. This may be accomplished by the use of clamshells, scoops, grills, funnels, louvers, etc. No test is necessary. See Figure 11.

2.   Conduct a test, to verify that air will flow either in or out of all openings provided for use as a "natural ventilation system". Air does not have to flow in both directions but merely has to flow into or out of each opening during the test

AIR FLOW TEST

Test Location — The test should be conducted in an area clear of obstructions to assure an even air flow around all surfaces of the test boat. A large parking lot, on the water, and in a large open doorway have been used successfully to run this test.

Test Boat Orientation -- The test boat must be placed so that the bow of the boat is headed toward the source of the wind or air flow and the boat's centerline aligned with the direction of air flow. If the test is conducted using natural wind conditions this orientation may have to be averaged due to small shifts in wind direction. If the test is conducted under more laboratory type of conditions then the air flow source and direction can be more accurately controlled.

Air Flow Velocity – The air flow or wind is to be no more than 10 miles per hour over the test boat in order for the test to be valid. Adjustments to achieve a ten miles per hour air flow velocity may be made by:

- using a variable air flow source such as a controllable wind generator.

- towing the boat by another boat to increase the wind velocity if the natural wind velocity is not sufficient. The test boat's engine is not to be operating.

   towing the boat on a trailer. The boat may be towed against the wind or with the wind in order to achieve the correct air flow from bow to stern.

-- adjusting the size of openings in one end of a building that is used as a wind tunnel with the boat at the other end of the building in a doorway.

To measure the air flow there are a number of meters available. A meter should be chosen to be accurate at the ten miles per hour velocity in order for the test to be valid.

Air Flow Verification   The object of the test is to determine if there is air flowing into or out of openings, supply or exhaust, provided for natural ventilation purposes. To verify that there is air flow in or out is sufficient as there is no air flow velocity specified for these openings. There are a number of ways to indicate if there is or is not air flow in the vent opening:

FIGURE 11 — FORWARD FACING SUPPLY OPENINGS

OPENING FACING FORWARD

TO BOW

FUNNEL — OPENING FACING FORWARD

TO BOW

LOUVER VANES SHOULD EXTEND AT LEAST ¼" FROM THE HULL SURFACE
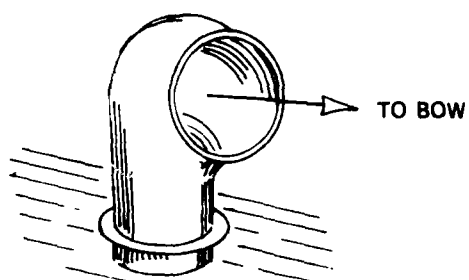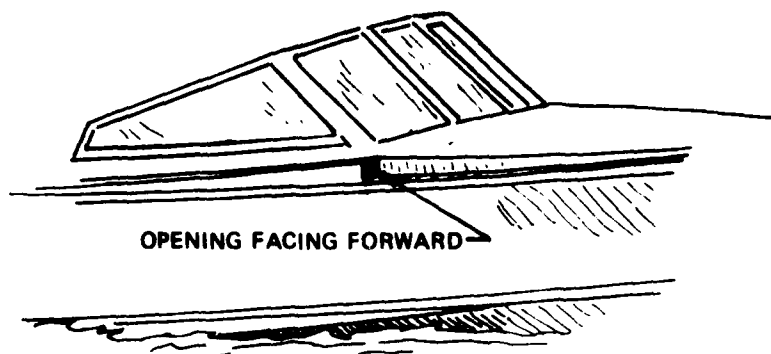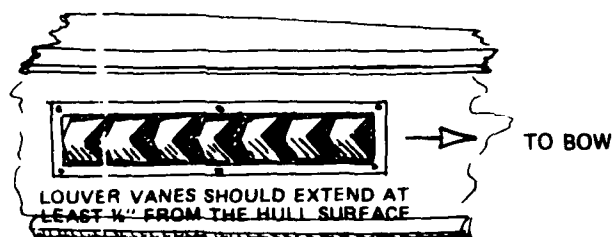
LOUVERS — OPENINGS FACING FORWARD

TO BOW
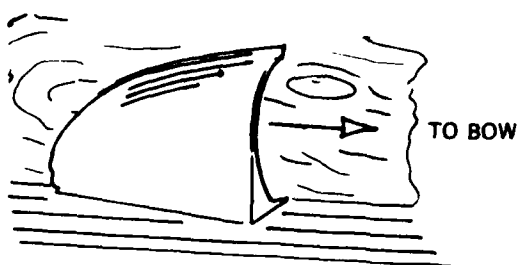
COWL — OPENING FACING FORWARD
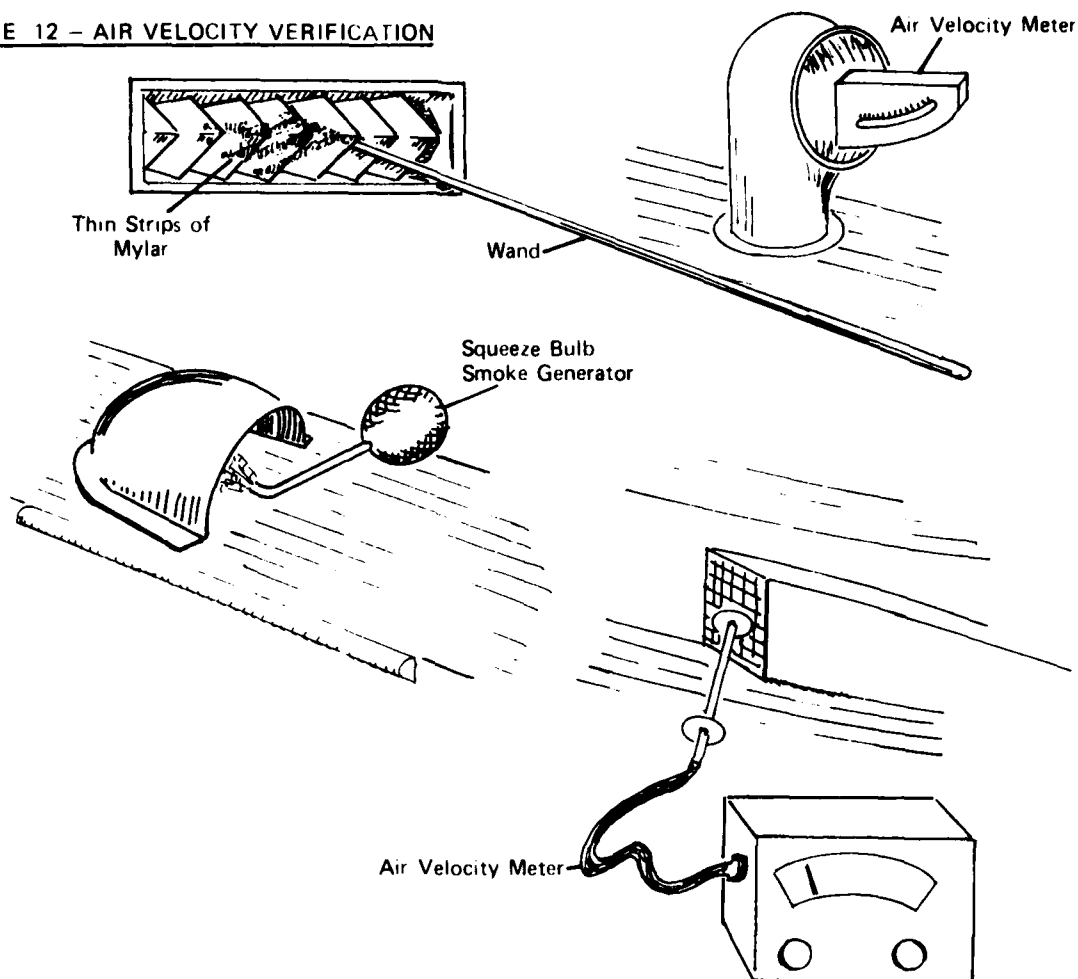

TO BOW
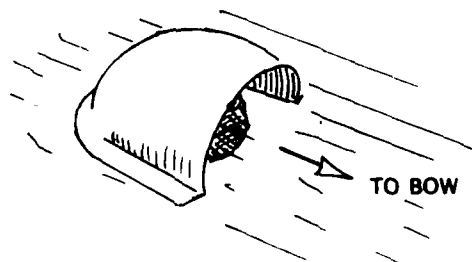
CLAMSHELL — OPENING FACING FORWARD

TO BOW
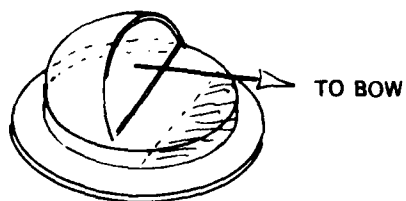
PLASTIC VENT — OPENING FACING FORWARD

TO BOW
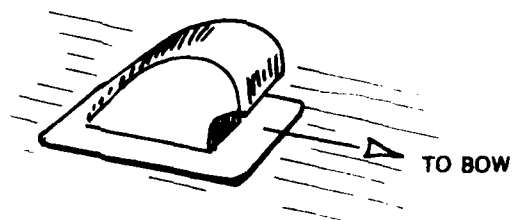
CABIN TOP VENT — OPENING FACING FORWARD

FIGURE 12 – AIR VELOCITY VERIFICATION

Air Velocity Meter

Thin Strips of
Mylar

Wand

Squeeze Bulb
Smoke Generator

Air Velocity Meter

an air flow velocity meter may be used even though velocity readings need not be taken. It is to be noted however, that a recorded reading is a verification of air flow. See Figure 12.

tufts of fabric or fine threads may be fastened inside the openings or attached to a wand that is held inside the openings and observed to see if there is air flow.

chemicals such as titanium tetrachloride that will give off a smoky vapor in the presence of air flow may be used, however, extreme caution should be exercised in the event that the chemical or its vapor may be toxic.

smoke generators, there are hand operated puff types, have proven successful.

finely shredded strips of paper or plastic may be used in the same way threads might be used.

Documentation   There is not specific requirements for recording information or how to certify that successful test has been conducted. It is, however, good practice to record each test that is conducted. A report should include:

date of test

- test conditions

test location and placement of test boat. A diagram or photographs are extremely helpful for this information.

test procedure, a step-by-step description of what was done and how air flow was determined.

the test results, stating the position of each opening and if air flow was detected. Diagrams, photographs and air flow readings can be helpful to demonstrate compliance with this part of the regulation.

DO YOU COMPLY

Answer "YES" to one of the following:

Are all supply openings, for the "natural ventilation system", facing forward?, or   (   )

Is there detectable air flow, in or out, in both supply exhaust openings when the boat is headed into a 10 miles per hour air flow or wind?   (   )

IT'S THE LAW

183.620   NATURAL VENTILATION SYSTEM

(c)   An accommodation compartment above a compartment requiring ventilation that is separated from the compartment requiring ventilation by a deck or other structure is excepted from paragraph (a)(2) of this section.

EFFECTIVE DATE   August 1, 1980
(Compliance on or after August 1, 1978 is acceptable.)

The discussion of this section was included with that of section 183.620(a)(2). Please refer to pages 67 and 68.

IT'S THE LAW

183.630   STANDARDS FOR NATURAL VENTILATION

(a)   For the purpose of 183.620 "natural ventilation" means an airflow in a compartment in a boat achieved by having

(1)   A supply opening or duct from the atmosphere or from a ventilation compartment or from a compartment that is open to the atmosphere; and

(2)   An exhaust opening into another ventilated compartment or an exhaust duct to the atmosphere.

EFFECTIVE DATE: August 1, 1980
(Compliance on or after August 1, 1978 is acceptable.)

NATURAL VENTILATION SYSTEM

A Natural Ventilation System must have two elements:

-- A supply opening or duct, and

- An exhaust opening or duct.

NOTE: An exhaust duct may serve for both the "Natural Ventilation System" and the "Powered Ventilation System".

SUPPLY

The supply opening or duct may take air in from any of the following three choices: (Also see Figure 13)

1. Atmosphere -- This arrangement usually involves an opening on the outside surface of the boat. It may be fitted with a cowl, louver, clamshell, or other suitable ventilation terminal fitting. Such fittings must be forward facing.

2. Ventilated Compartment -- A supply opening or duct may be installed to take in air from a compartment that is required to be ventilated (See requirements for determining which compartments need to be ventilated contained in 183.610(a) and 183.620(a).

3. Compartments Open to the Atmosphere -- A supply opening or duct may be installed to take air in from a compartment that qualifies as "open to the atmosphere" as described in 183.605.

EXHAUST

The exhaust has two options for its point of discharge: (Also see Figure 13)

1. Atmosphere -- If the exhaust discharge point is directly into the atmosphere there must be a duct from the air and/or vapors intake point to the exhaust discharge point which is usually at the deck or hull side *near the deck.*

2. Ventilated Compartment -- An exhaust opening may be located in a bulkhead or other structure that separates "ventilated compartment" from the compartment in which the natural ventilation system is being considered. The "ventilated compartment" into which the exhaust opening discharges may not be the same "ventilated compartment" that contains a supply opening or duct for the compartment being considered.

DO YOU COMPLY

Underline One of the following must be answered "YES".

Is the supply opening or duct from:

- the atmosphere   (   )
- a ventilated compartment, or   (   )
- a compartment that is "open to the atmosphere"   (   )

One of the following must be answered "YES"

Is there an exhaust opening into a ventilated compartment other than that in which the supply is located?   (   )

Is there an exhaust duct to the atmosphere?   (   )

FIGURE 13 NATURAL VENTILATION— SUPPLY AND EXHAUST OPTIONS

ATMOSPHERE

Exhaust (Opening facing aft)
ducted to Lower Third of
Compartment

Supply (Opening Facing
Forward)

VENTILATED COMPARTMENTS

Ventilated Compartments

Exhaust

Supply

Compartment needing
Natural Ventilation

Exhaust opening for ventilated
compartment is the Supply opening
for compartment needing ventilation

COMPARTMENT THAT IS OPEN TO THE ATMOSPHERE

Exhaust to atmosphere
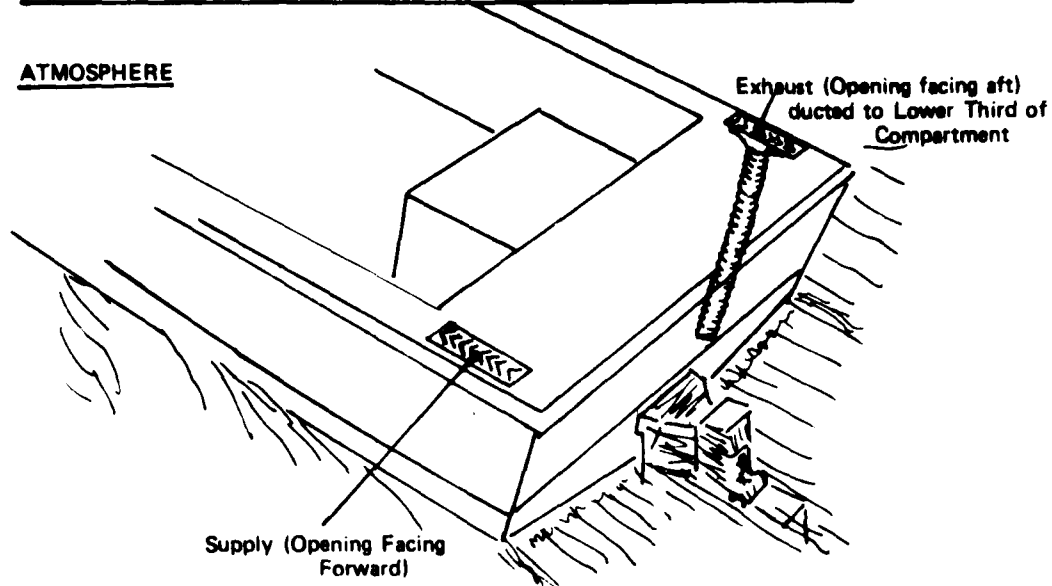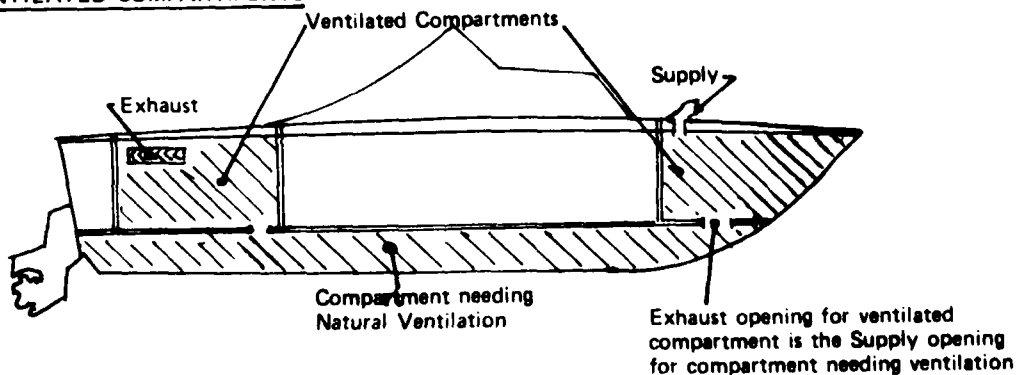
Compartment open
to the atmosphere
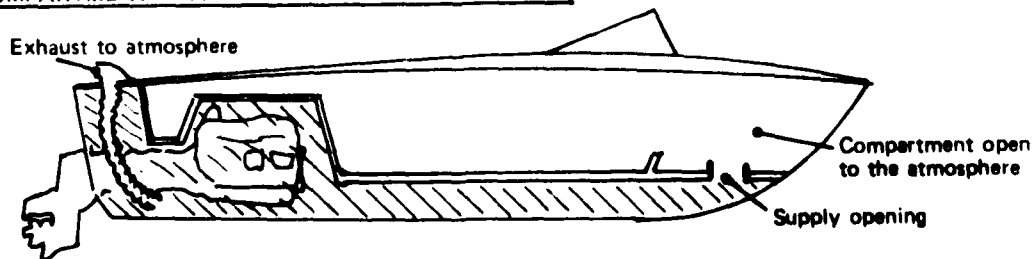
Supply opening

NOTE: Air flow test required for this type of configuration because Supply opening is not on exterior of the boat.

80

183.630   STANDARDS FOR NATURAL VENTILATION

(b)   Each exhaust opening or exhaust duct must originate in the lower third of the compartment.

EFFECTIVE DATE: August 1, 1980
(Compliance on or after August 1, 1978 is acceptable.)

The location of an exhaust opening or an exhaust duct intake opening is required to be in the lower third of the compartment in which it is part of the natural ventilation system. The intent is for the exhaust opening to be in a position to remove any flammable or explosive vapors as air from the supply, circulates through the compartment and discharges through the exhaust.

If there is uncertainty as to the upper limit of the lower third, perhaps due to a complex shaped compartment, keep in mind that the lower the exhaust opening or duct intake is located in a compartment the more effective it is. Normal bilge water level must also be considered as stated in 183.603(c).

Ideally the exhaust opening or duct intake should be positioned in the lowest part of the compartment where vapors are likely to accumulate. It would then be reasonable to measure the height of the compartment at the position of the exhaust opening or duct intake to determine the lower third level. (See Figure 14)

FIGURE 14: LOWER ONE THIRD OF COMPARTMENTS

Lower one third of engine compartment

Lower one third of compartment under cockpit floor

Lower one third of bow compartment
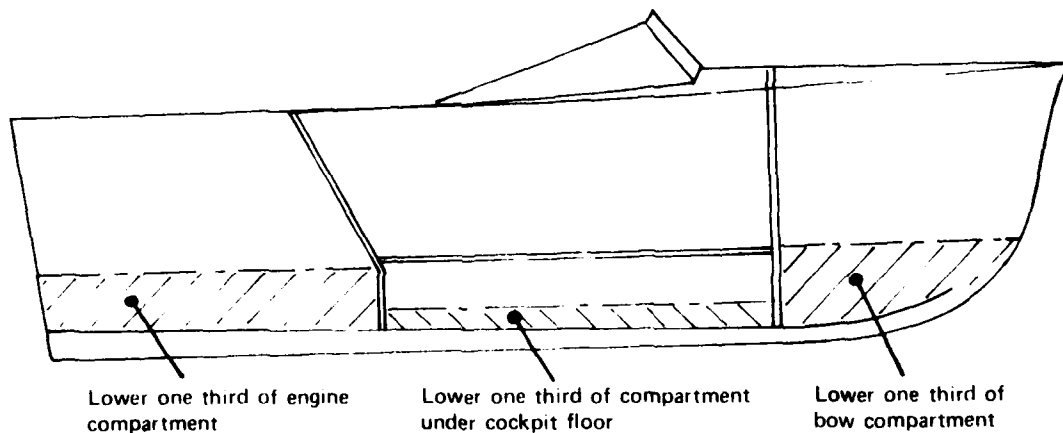
Are exhaust openings and duct intake openings located in the "lower third of the compartment"? (   )

IT'S THE LAW

183.630   STANDARDS FOR NATURAL VENTILATION

    (c)   Each supply opening or supply duct and each exhaust opening or exhaust duct in a compartment must be above the normal accumulation of bilge water.

EFFECTIVE DATE: August 1, 1980
(Compliance on or after August 1, 1978 is acceptable.)

Consideration must be given to the possibility of normal bilge water accumulations covering the intake opening. "Normal accumulations of bilge water" is that which occurs from propeller shaft stuffing box seepage, spray while operating the boat, and rain. The water remaining in the boat after a bilge pump completed its normal running cycle would be considered normal. The openings and duct intakes of both supply and exhaust must be above this "normal level of accumulated bilge water.".

It is important to evaluate each compartment design and to locate the openings and ducts so they will be in the best positions to cause an effective removal of any accumulated vapors.

DO YOU COMPLY

Are both supply and exhaust openings and ducts located above the "normal accumulation of bilge water"?   (   )

183.630 STANDARDS FOR NATURAL VENTILATION

(d) Except as provided in paragraph (e) of this section, supply openings or supply ducts and exhaust openings or exhaust ducts must each have a minimum aggregate internal cross-sectional area calculated as follows :

$$A = 5 \ \ln (V/5);$$

where:

(1) A is the minimum aggregate internal cross—sectional area of the openings or ducts in square inches;

(2) V is the net compartment volume in cubic feet, including the net volume of other compartments connected by openings that exceed 2 percent of the area between compartments; and

(3) ln (V/5) is the natural logarithm of the quantity (V/5).

EFFECTIVE DATE: August 1, 1980
(Compliance on or after August 1, 1978 is acceptable)

The minimum total cross-sectional area of all supply openings and ducts in a compartment is determined by the use of the formula. The formula is also used to determine the minimum total cross-sectional area of all exhaust openings and ducts in a compartment.

THE FORMULA

$$A = 5 \ \ln (V/5)$$

The formula stated in words is:

the cross-sectional area of either the supply openings and ducts or the exhaust openings and ducts (in square inches) equals five times the natural logarithm of one fifth the net compartment volume in cubic feet.

To use the formula:

determine the net compartment volume (V) in cubic feet. The net volume of connecting compartments must be included if the openings in the separation structure is more than 2% of the area of the separation structure between the compartments. The exception stated in 183.620(c) for accommodation compartments, above a compartment requiring ventilation and separated by a deck or other structure, may be applied.

divide the net compartment volume (V) by 5.

determine the natural logarithm (ln) of V/5. Natural Logarithm are tabulated in books of mathematical tables, engineering handbooks, trigonometry textbooks etc. Figure 15 is a Table of Natural Logarithms.

Multiply the natural logarithm by 5.

The result is the minimum required area (A) in square inches.

For convenience Figure 16 is a graph of the formula. Entering the graph with the Net Compartment Volume in cubic feet you can read the area of openings and ducts directly along the vertical scale on the left of the graph.

The graph must be considered approximate. The formula provides the accurate area.

FIGURE 15 – NATURAL LOGARITHMS

These two pages give the natural or Napierian logarithms (ln) of numbers between 1 and 10, correct to four places. Moving the decimal point n places to the right (or left) in the number is equivalent to adding n times 2.3026 (or n times 3.6074) to the logarithm. Base e = 2.71828 +

n (2.3026)		n (0.6074-3)	
1	2.3026	1	0.6974−3
2	4.6052	2	0.3948−5
3	6.9078	3	0.0922−7
4	9.2103	4	0.7897−10
5	11.5129	5	0.4871−12
6	13.8155	6	0.1845−14
7	16.1181	7	0.8819−17
8	18.4207	8	0.5793−19
9	20.7233	9	0.2767−21

FIGURE   16 -   AREA OF OPENINGS

FIGURE   16 -   AREA OF OPENINGS

PLOT OF (V) VOLUME vs (A) AREA OF OPENINGS
BASED ON THE FORMULA $A = I_n (V/5)$

NET COMPARTMENT VOLUME   CU. FT.

AREA OF OPENINGS – SQUARE INCHES

NET COMPARTMENT VOLUME – CU. FT.

IT'S THE LAW

183.630   STANDARDS FOR NATURAL VENTILATION

(e)   The minimum internal cross–sectional area of each supply opening or duct and exhaust opening or duct must exceed 3.0 square inches.

EFFECTIVE DATE: August 1, 1980
(Compliance on or after August 1, 1978 is acceptable.)

The shape of the opening is not specified but to give an idea of what three square inches looks like, Figure 17 depicts a few common geometric shapes each of which is three square inches.

FIGURE 17: THREE SQUARE INCHES
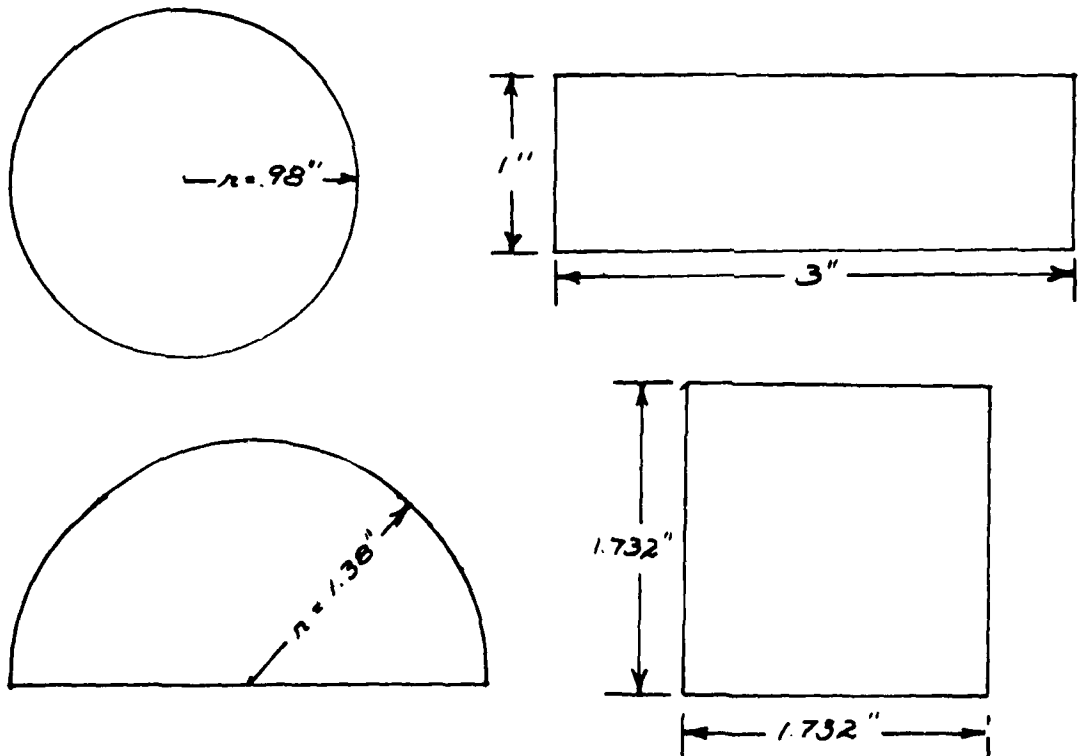
The regulation requires each opening and each duct, whether a supply or an exhaust, to have more than 3.0 square inches in cross sectional area. Therefore openings and ducts must be larger than those shown in Figure 17.

IT'S THE LAW

183.630   STANDARDS FOR NATURAL VENTILATION

(f)   The minimum internal cross-sectional area of terminal fittings for flexible ventilation ducts installed to meet the requirements of paragraph (d) of this section must not be less than 80 percent of the required internal cross-sectional area of the flexible ventilation duct.

EFFECTIVE DATE: August 1, 1980
(Compliance on or after August 1, 1978 is acceptable.)

Some of the flexible ventilation ducts that are available for marine use may be fitted with terminal fittings made to fit the duct. Some of these fittings are designed to fit inside the flexible duct. For these fittings the reduced cross sectional area at the fitting is permitted to be not less than 80% of the cross sectional area required for the flexible duct under consideration. It is important to remember that this reduction in cross sectional area is only permitted inside a terminal fitting. No reduction in cross sectional area is permitted anyplace in the natural ventilation system. Also the cross sectional area of the terminal fitting is not required to be at least 80% of the duct cross sectional area but is required to be 80% of the required area for the duct. The duct may be oversized for the specified area required since only certain sizes are available.
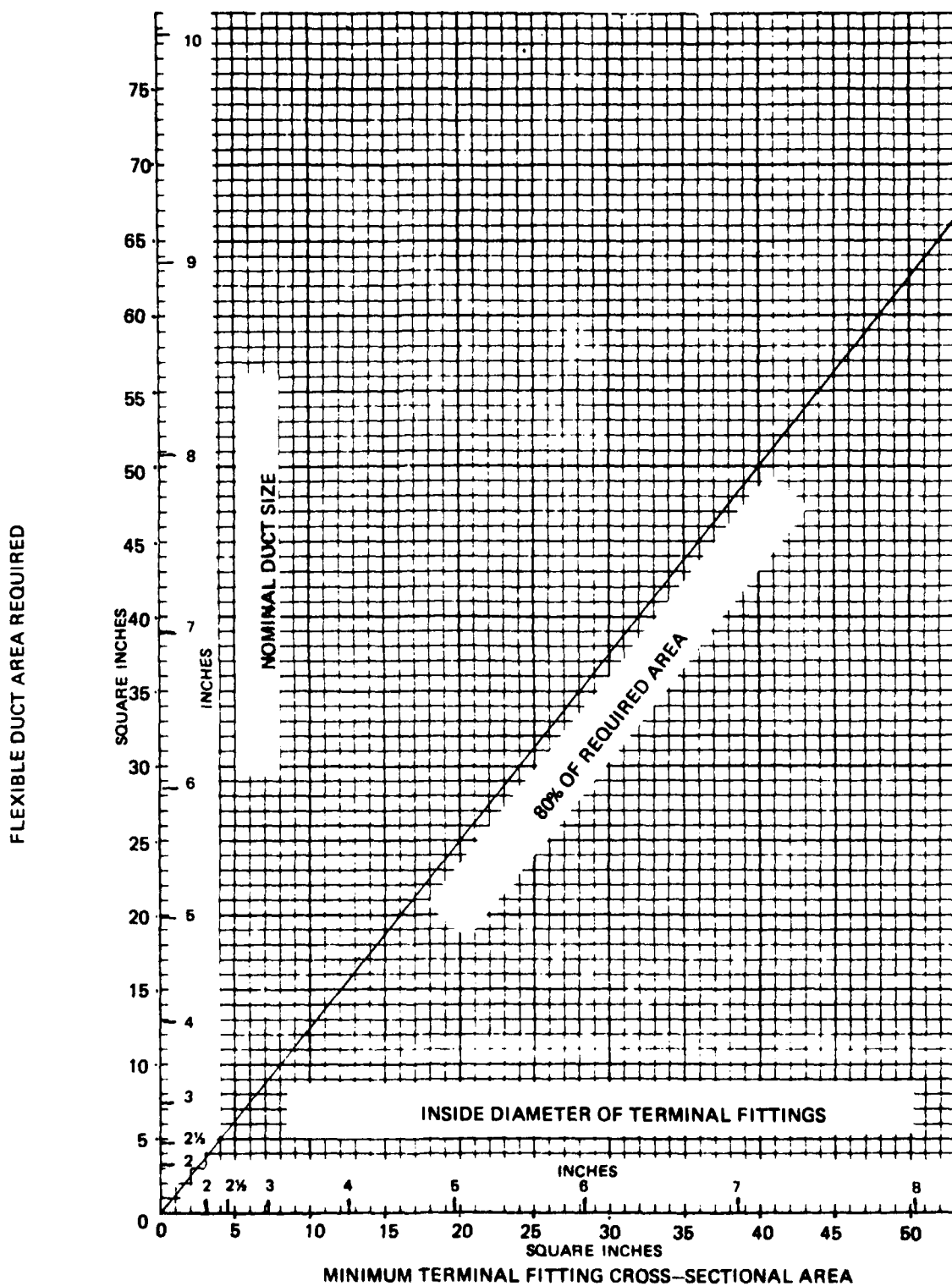
Figure 18 is a graph that is intended to aid in determining compliance. The minimum terminal fitting cross sectional area must be at or above the "80% of required area" line in order to comply with this section of the regulation. The diameters at the various areas are included on the graph to aid in evaluating terminal fittings by simply measuring their inside diameters.

This discussion and graph has assumed that circular ducts will be used. If other shapes of flexible ducts are used the same principles apply but their measurements and area calculation must be appropriate for the shape under consideration.

DO YOU COMPLY

Is the cross sectional area of the terminal fitting for a flexible duct at least 80% of the cross sectional area required for the duct?   (   )

FIGURE 18 – TERMINAL FITTING AREA

MINIMUM TERMINAL FITTING CROSS–SECTIONAL AREA

END

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